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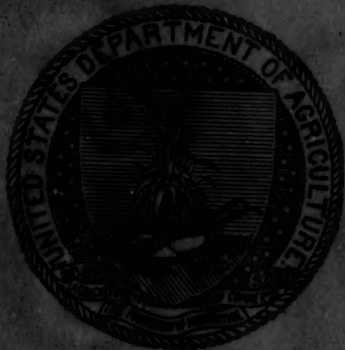
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CORRECTION

MONTHLY WEATHER REVIEW, October, 1925, 53:

Page 426, first column, first line, "dotted curve" should be "dot-dash curve"; fourteenth line, "dot-dash line" should be "dotted line"; same page, legend to Figure 1, for the four lines substitute "sun" for "shade" and "shade" for "sun."

Page 60, in table, column headed "Remarks," for tornado of March 18, 1925, after the figures for De Soto and vicinity, add "Bush, Ill., and vicinity, 13 and 33." In last line, change Indiana figures to "70" and "354," respectively. Add: "Entire tornado, 689 and 1980"

ON THE SOLUTION OF PROBLEMS OF ATMOSPHERIC MOTION F   ...EANS OF MODEL EXPERIMENTS

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[Weather Bureau, Washington, D. C., March 26, 1926]

The difficulties which arise when we try to integrate the fundamental equations of hydrodynamics, and which are due to their complicated, nonlinear form, have long since forced branches of this science to abandon the classical theoretical lines of work for new and more fertile practical methods. The impossibility of expressing in a satisfactory mathematical way the laws and the influences of the disturbing phenomena which we generally include under the name of turbulence, has doubtless contributed to this change. In naval architecture and in aerodynamics, experimental methods have been used for many years. I need only to remind the reader of Eiffel's famous experiments for determinating the resistance of air against differently shaped bodies. Through the invention of airships and airplanes these methods have gained an increased importance. The circulation and pressure distribution around wings and propellers are nowadays determined by means of model experiments in wind tunnels; from these observations the corresponding data for full scale airplanes are obtained through an easy computation.

The possibility of this full scale computation depends entirely upon the existence of *similar motions*. Following closely the methods of Bairstow (1), I shall here try to develop the fundamental conception of *dynamic similarity*.

The movement of a fluid within a given space (A') can be described by the three hydrodynamical equations (supplemented by the equation of continuity and certain boundary conditions). The first of these equations has the following form in the case of the motion of an incompressible fluid under no external forces referred to an inertial frame:

$$(1) \qquad \rho' \frac{du'}{dt'} = -\frac{\delta p'}{\delta x'} + \mu' \left[\frac{\delta^2 u'}{\delta x'^2} + \frac{\delta^2 u'}{\delta y'^2} + \frac{\delta^2 u'}{\delta z'^2} \right]$$

Here ρ' means the density, p' the pressure, μ' the viscosity, u', v', and w' the components of velocity along the axes of x', y', and z'; t' is the time.

For $\frac{du'}{dt'}$ we have the expression

$$\frac{du'}{dt'} = \frac{\delta u'}{\delta t'} + u' \frac{\delta u'}{\delta x'} + v' \frac{\delta u'}{\delta y'} + w' \frac{\delta u'}{\delta z'}$$

Thus $\frac{du'}{dt'}$ means the x'-component of acceleration of an individual fluid element.

We now demand similar movement of another liquid in a similar space (A), the linear dimensions of which are $\frac{1}{L}$ of the dimensions of A'. By similarity we then mean,

that corresponding to any of the instantaneous config urations of stream lines and isobaric surfaces in (A') there could be found a similar configuration in (A). The sequence of corresponding states of motion generally runs at different rates in the two spaces; the ratio between corresponding times in (A') and (A) or the time scale may be called T.

The equations of motion for the space A have the form

$$(2) \qquad \rho \frac{du}{dt} = -\frac{\delta p}{\delta x} + \mu \left[\frac{\delta^2 u}{\delta x^2} + \frac{\delta^2 u}{\delta y^2} + \frac{\delta^2 u}{\delta z^2} \right],$$

where notations similar to those in equation (1) are used. With the above given values for length and time scales, we easily obtain the following relations between corresponding quantities in A' and A:

$$dx' = L dx, \; dy' = L dy, \; dz' = L dz, \; dt' = T dt$$

$$(3) \qquad u' = \frac{L}{T} u, \quad \frac{du'}{dt'} = \frac{L}{T^2} \frac{du}{dt}, \quad \frac{\delta^2 u'}{\delta x'^2} = \frac{1}{LT} \frac{\delta^2 u}{\delta x^2}$$

Introducing the kinematic coefficients of viscosity, $v' = \frac{\mu'}{\rho'}$ and $v = \frac{\mu}{\rho}$, we see that (1) can be written in the form

$$\frac{L}{T^2} \frac{du}{dt} = -\frac{\rho}{\rho'} \frac{dp'}{dp} \cdot \frac{1}{L} \frac{1}{\rho} \frac{\delta p}{\delta x} + \frac{v'}{v} \cdot \frac{v}{LT} \left[\frac{\delta^2 u}{\delta x^2} + \frac{\delta^2 u}{\delta y^2} + \frac{\delta^2 u}{\delta z^2} \right]$$

or

$$(1b) \qquad \frac{du}{dt} = -\frac{\rho T^2}{\rho' L^2} \frac{dp'}{dp} \frac{1}{\rho} \frac{\delta p}{\delta x} + \frac{Tv'}{L^2 v} \cdot v \left[\frac{\delta^2 u}{\delta x^2} + \frac{\delta^2 u}{\delta y^2} + \frac{\delta^2 u}{\delta z^2} \right]$$

If now the two motions are similar, the equations (1b) and (2) must be identical; thus we obtain the following necessary conditions

$$(4a) \qquad \frac{v'}{v} \frac{T}{L^2} = 1; \; (4b) \; \frac{\rho}{\rho'} \frac{T^2}{L^3} \frac{dp'}{dp} = 1$$

Let us denote by U' a characteristic velocity and by D' a characteristic length in A'; letting U and D be the corresponding quantities in A. The condition (4a) can then be written

$$(5) \qquad \frac{U' D'}{v'} = \frac{UD}{v}$$

$\frac{U'D'}{v'}$ is a nondimensional pure number, which generally is denoted as Reynold's number. A condition necessary for dynamical similarity is therefore, that the two systems should have the same Reynold's number.

If we suppose the two liquids and the length scale L to be given, the condition (4a) will, obviously, fix the time scale.

The ratio between corresponding pressure differences in (A') and (A) can be obtained from (4b), which may be written

$$(6a) \qquad \frac{dp'}{dp} = \frac{\rho'}{\rho} \frac{L^2}{T^2}$$

or

$$(6b) \qquad \frac{dp'}{dp} = \frac{\rho'}{\rho} \frac{U'^2}{U^2}$$

The equation (6b) does not involve a new condition but could easily be derived through a consideration of dimensions.

From the form of Reynold's number a conclusion can be drawn, which later will prove to be of a certain importance. If we magnify the linear dimensions of a system, the Reynold's number will change in the same way as if we had kept the dimensions constant but diminished the coefficient of viscosity. We may therefore conclude that the influence of internal friction more and more decreases with increasing dimensions of the system considered.

Until now we have considered motions which take place solely under the influence of internal forces, viz, pressure gradients and friction. Atmospheric movements are however essentially determined by the action of gravity (g). If this force be introduced we obtain a new relation between L and T. The equation for the motion along the vertical axis takes the form

$$(7a) \qquad \frac{dw'}{dt'} = -\frac{1}{\rho'}\frac{\delta p'}{\delta z'} - g + \nu'\left[\frac{\delta^2 w'}{\delta x'^2} + \frac{\delta^2 w'}{\delta y'^2} + \frac{\delta^2 w'}{\delta z'^2}\right]$$

or

$$(7b) \qquad \frac{L dw}{T^2 dt} = -\frac{\rho}{L\rho'}\frac{dp'}{dp}\cdot\frac{1}{\rho}\frac{\delta p}{\delta z} - g + \frac{\nu'}{\nu}\frac{\nu}{LT}\left[\frac{\delta^2 w}{\delta x^2} + \frac{\delta^2 w}{\delta y^2} + \frac{\delta^2 w}{\delta z^2}\right]$$

After multiplication with $\frac{T^2}{L}$ and reductions by means of (4a) and (4b) the equation (7b) can be reduced to

$$(7c) \qquad \frac{dw}{dt} = -\frac{1}{\rho}\frac{\delta p}{\delta z} - \frac{T^2}{L}g + \nu\left[\frac{\delta^2 w}{\delta x^2} + \frac{\delta^2 w}{\delta x^2} + \frac{\delta^2 w}{\delta z^2}\right]$$

The corresponding equation for the space A can be written

$$(8) \qquad \frac{dw}{dt} = -\frac{1}{\rho}\frac{\delta p}{\delta z} - g + \nu\left[\frac{\delta^2 w}{\delta x^2} + \frac{\delta^2 w}{\delta y^2} + \frac{\delta^2 w}{\delta z^2}\right]$$

Comparing (7c) and (8), which must be identical in the case of similarity, we obtain as a necessary condition

$$(9a) \qquad L = T^2$$

or

$$(9b) \qquad \frac{U'^2}{D} = \frac{U^2}{D}$$

Combining (9a) with (4a) we see that our liberty in the choice of scales and model fluid has now become very restricted. If the model fluid is given, the conditions (4a) and (9a) will fix the two scales.

It may now be questioned whether the introduction of the deviating force of the earth's rotation will lead to any new necessary conditions. The answer is easily obtained. This force is proportional to the angular velocity (Ω') of the earth at the latitude considered. To obtain similarity we must obviously give the model vessel a certain angular velocity, which may be denoted by Ω. Now, Ω' and Ω have the dimensions of an inverse time; they must therefore fulfill the relation

$$(10) \qquad \Omega' = \frac{1}{T}\Omega$$

However, since we are able within a wide range to give the vessel arbitrary angular velocities, this condition will not restrict our choice of scales and model fluid.

The practical value of the conception of dynamic similarity obviously lies in the fact that we in some cases may be able to observe and measure, in a model experiment, quantities which in the original space A' are beyond our reach. Multiplying the observed data by certain powers of $\frac{\rho'}{\rho}$, L, and T, according to the dimensions of the quantities considered, we can then easily obtain the required values for the original space, provided the necessary conditions (4a) and (9a) are fulfilled.

Suppose now, that we have observed a certain synoptic distribution of density and velocity in the atmosphere. As already pointed out, it is generally impossible to compute mathematically the movements which will develop from this original state. However, if we are able to imitate in a model (A) the observed initial conditions, this space will act as a kind of mechanical integrator. If we then study and measure the model movements by means of a motion-picture camera, certain computations will give us the corresponding states of motion in the atmosphere.

In the attempt to apply this method to meteorological problems, several serious difficulties will arise. Most atmospheric movements take place under simultaneous gain and loss of heat, and these thermal processes often have a marked influence upon the state of motion. The above suggested method would therefore require the extension of the conception of similarity also to the thermal phenomena, which would be impossible.

Even if we limit our study to pure adiabatic movements, the compressibility of the air will introduce a new condition necessary for dynamic similarity. However, in the large atmospheric movements, which are principally horizontal, the influence of compressibility can generally be neglected; in which case the new condition may be disregarded.

Proceeding now under this assumption, the air as studied by us is reduced to an incompressible fluid. Provided the two conditions (4a) and (9a) are fulfilled, we then ought to be able to use model experiments in the study of this atmosphere. However, our liberty in the choice of model fluid and scales is so restricted by these two conditions, that the experiments become practically impossible. We will therefore limit our study to problems in which the atmosphere may be regarded as a first approximation may be regarded as an ideal, nonviscous fluid. It has been pointed out above that the influence of viscosity will increase as the dimensions of the system decrease. Thus, even if this assumption be justified for the atmosphere, it is a question whether it will apply to the model movements; a satisfactory answer can probably be obtained only from the experiments themselves. It will obviously be necessary to use for the experiments liquids which are as fluent as possible. In any case the viscosity will play a much greater rôle in the model (A) than in reality; no numerical conclusions as to the rate of dissipation of kinetic energy could, therefore, be drawn from measurements in (A).

We have now reduced the atmosphere to an ideal, incompressible liquid. Of the conditions for dynamic similarity only one remains, viz:

$$L = T^2$$

Suppose now, that the movements which we intend to study extend over a horizontal area of about 2,000 km. in diameter, i. e., about the distance between Key West and New York. In vertical direction they reach the upper limit of the troposphere, i. e., about 10 km. high. If we construct a model of this space, using a length scale of $L=10^6$, this portion of the atmosphere would correspond to a circular liquid layer of only 1 cm. thickness but with 2 m. diameter. In order to imitate air masses of different temperature we have to use nonmiscible liquids of slightly different densities. Due to the small thickness of the liquid layers considered, their movements will become strongly influenced by surface tensions and irregularities at the bottom of the model vessel. Obviously the small height of the atmosphere compared with its horizontal extension acts as a great obstacle against the use of model experiments in dynamical meteorology.

To avoid this difficulty we will now assume, that the vertical velocities and accelerations may be neglected in the dynamical equations. In most large-scale atmospheric movements this assumption is justified. The equations of motion in (A') will then take the following form:

$$(11) \qquad \begin{aligned} \frac{\rho' du'}{dt'} &= -\frac{\delta p'}{\delta x'} \\[2mm] \rho' g &= -\frac{\delta p'}{\delta z'} \end{aligned}$$

We now seek a corresponding state of motion in a model space (A). This space is obtained by using one length scale, L, for horizontal distances, and another, l, for the vertical, the time scale, as before, being T. Thus we get:

$$(12) \qquad dx'=Ldx,\ dy'=Ldy,\ dz'=ldz,\ dt'=Tdt$$

We will now show, that under the above assumption (neglecting the vertical velocities and accelerations in the equations of motion) dynamical similarity may be obtained, provided one necessary condition is fulfilled. By means of (12) the equations (11) can be transformed into:

$$(11b) \qquad \begin{aligned} \frac{L}{T^2}\frac{\rho'}{\rho}\cdot\rho\cdot\frac{du}{dt} &= -\frac{1}{L}\left(\frac{dp'}{dp}\right)_{\text{horizontal}}\cdot\frac{\delta p}{\delta x} \\[2mm] \frac{\rho'}{\rho}\rho g &= -\frac{1}{l}\left(\frac{dp'}{dp}\right)_{\text{vertical}}\cdot\frac{\delta p}{\delta z} \end{aligned}$$

The corresponding equations for the model experiment are:

$$(13) \qquad \begin{aligned} \rho\frac{du}{dt} &= -\frac{\delta p}{\delta x} \\[2mm] \rho g &= -\frac{\delta p}{\delta z} \end{aligned}$$

Since the systems (11b) and (13) must be identical, we have:

$$(14) \qquad \begin{aligned} \left(\frac{dp'}{dp}\right)_{\text{horizontal}} &= \frac{\rho'}{\rho}\frac{L^2}{T^2} \\[2mm] \left(\frac{dp'}{dp}\right)_{\text{vertical}} &= \frac{\rho'}{\rho}l \end{aligned}$$

Dynamic similarity obviously implies the condition that these two quantities be equal. We therefore obtain as a necessary condition:

$$(15) \qquad l=\frac{L^2}{T^2}$$

This equation can be regarded as a generalization of (9a). If we put $l=L$, the two conditions become identical. (15) may be written in the form

$$(15b) \qquad \frac{L}{l}=\frac{1}{\dfrac{L}{T^2}}$$

and is then open to a simple physical interpretation. Denoting two characteristic horizontal and vertical distances by D' and h', corresponding respectively to D and h, and a characteristic velocity by U', corresponding to U, we obtain

$$(15c) \qquad \frac{\dfrac{h}{D}}{\dfrac{h'}{D'}}=\frac{\dfrac{dU}{dt}}{\dfrac{dU'}{dt'}}$$

In this form the condition (15) denotes that the horizontal accelerations of the model movements will be magnified at the same rate as the vertical dimensions of the model are exaggerated.

The formula (15) can be applied with advantage also in comparing atmospheric systems of different vertical dimensions, especially in cases where the deviating force of the earth's rotation can be neglected. Suppose that we wish to determine the velocity with which a body of cold air, surrounded by warmer and lighter air, is dilating horizontally. Comparing two such bodies, the vertical dimensions of which have the ratio $\frac{l}{1}$, we see from (15), that the ratio between corresponding horizontal velocities is $\frac{L}{T}=\sqrt{l}$; that is, the horizontal velocity of a cold wave should be proportional to the square root of its height. Thus we find again in a more general way a result, which previously and by other means has been derived by Exner (2). In cases where the deviating force must be taken into consideration, the condition (15) reduces to

$$(15d) \qquad l=L^2,$$

since the time scale T now is equal to 1. This formula can be interpreted in the following way:

If we take any complete atmospheric system, a cyclone surrounded by homogeneous air at rest, for instance, and magnify the horizontal dimensions L times, the vertical dimensions l times, then the original and the new system are dynamically similar, provided $l=L^2$. In two dynamically similar atmospheric systems the ratio between corresponding horizontal velocities is equal to the square root of the ratio between corresponding vertical dimensions.

As an application and test of the condition (15) we will solve the following problem. A liquid in (A') is rotating about a vertical axis with the angular velocity Ω'. In the model vessel (A) another liquid is rotating with the angular velocity Ω. It is to be shown that the free surface in (A) can be obtained from the free surface in (A') by use of the transformation

$$(16) \qquad x'=Lx,\ y'=Ly,\ z'=lz,\ t'=Tt'$$

The free surface in (A') is a surface of constant pressure. We have

$$p' = \text{const.} - \rho' g z + \frac{\rho' \Omega'^2 (x'^2 + y'^2)}{2}$$

Thus, omitting a constant, we have at the free surface

$$(17) \qquad z' = \frac{\Omega'^2}{2g}(x'^2 + y'^2)$$

For the free surface in the model space (A) we obtain in the same way

$$(18) \qquad z = \frac{\Omega^2}{2g}(x^2 + y^2)$$

To show that the latter surface can be derived from the former through the transformation (16), we must first determine the time scale. Since angular velocity has the dimension of an inverse time, we have

$$(19) \qquad \Omega' = \frac{1}{T}\Omega$$

Thus we obtain from (16), (17) and (19)

$$(20) \qquad l z = \frac{\Omega^2}{2g}\frac{L^2}{T^2}(x^2 + y^2)$$

Since, according to (15),

$$l = \frac{L^2}{T^2}$$

the equations (20) and (18) become identical, q. e. d.

Making allowance for (15), we will now construct a model vessel suitable for our experiments. As is well known, atmospheric movements are to a considerable extent determined by the deviating force of the earth's rotation. Our first task is therefore to imitate this force in a convenient way. This can be done by making the experiments in a vessel, rotating about a vertical axis at an angular velocity Ω of say, n rotations per minute $\left(\Omega = \frac{2\pi n}{60}\right)$. Now the earth's surface is everywhere orthogonal to the apparent gravity. This would not be the case in a rotating vessel with plane bottom, since the rotation produces a horizontal, outwardly directed centrifugal force. The equipotential surfaces for the resultant of gravity and centrifugal force are paraboloids of the form

$$(21) \qquad z = \frac{\Omega^2}{2g}(x^2 + y^2)$$

In order to produce dynamic similarity we must give the bottom of the vessel the form of an equipotential surface. For this purpose the following procedure, suggested by Professor Humphreys, may be useful. The rotating vessel is partly filled with melted paraffin, the free surface of which will gradually assume the form (21). Keeping the vessel in rotation until the paraffin is solidified, we obtain the bottom form desired. This method

has the additional advantage that the surface form can easily be changed when a new speed of rotation is chosen.

Suppose, that the atmospheric phenomena which we intend to study take place at about 45° north latitude within a circular area of 4,000 km. diameter and are entirely restricted to the troposphere (10 km.). Using a height scale of

$$l = 25.10^4$$

and a length scale of

$$L = 2.10^6$$

we obtain for the time scale

$$T = 4.10^3$$

The portion of the atmosphere considered will then be imitated by a circular liquid layer of 4 cm. thickness and 2 m. diameter. Since the angular velocity Ω' of the earth at 45° north latitude has the value

$$\Omega' = \frac{2\pi \sin 45°}{24.60.60}$$

the number of rotations (n) may be determined from the equation

$$\frac{2\pi \sin 45°}{24.60.60} = \frac{1}{4.10^3} \cdot \frac{2\pi n}{60}$$

or

$$n = 1.96$$

The corresponding angular velocity is

$$\Omega = 0.205$$

From the values of L and T the following relation between corresponding velocities is obtained:

$$u' = \frac{L}{T}u = 5.10^2$$

Thus an atmospheric velocity of 5 m. p. s. will give a model velocity of 1 cm. p. s.

The exaggeration of the vertical dimensions in the model is given by

$$\frac{L}{l} = \frac{2.10^6}{25.10^4} = 8$$

Using the previously derived numerical value of Ω we can easily compute the elevation of the paraboloid (21) above the horizontal plane $z = 0$. In a distance of 50 cm. from the axis this elevation is only 0.5 mm. and amounts at the edge of the vessel to 2 mm.

The numerical constants of the model vessel are presented in Table 1.

TABLE 1.—*Numerical constants of the model vessel*

Length scale (L)	2×10^6.
Vertical scale (l)	25×10^4.
Exaggeration of height $\left(\frac{L}{l}\right)$	8.
Time scale (T)	4×10^3.
Rotations per min. (n)	1.96.
Angular velocity (Ω)	0.205.
Velocity scale $\left(\frac{L}{T}\right)$	5×10^2.
Height of troposphere (10 km.) in model	4 cm.
Diameter of system (4,000 km.) in model	2 m.
Bottom elevation 50 cm. from axis	0.5 mm.
Bottom elevation 100 cm. from axis	2.0 mm.

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1920. APPLIED AERODYNAMICS, (New York.)

(2) DYNAMISCHE METEOROLOGIE. (Vienna, 1925), p. 319.

OBSERVING WATER-SURFACE TEMPERATURES AT SEA[1]

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(Based mainly on observations made aboard the R. M. S. *Empress of Britain* during a four weeks' West Indies cruise, February to March, 1924.[2])

SYNOPSIS

This paper is largely a summary of water-surface temperature comparisons by the author on a winter-time West Indies cruise of the R. M. S. *Empress of Britain*. An attempt was made to determine the accuracy of observational methods under a great variety of conditions, including the most trying ones likely to be experienced. Temperatures obtained nearly simultaneously (1) from a low deck with a 2 or 4 quart tin bucket by quick dips forward of the ship's main outtakes and (2) aft in the propellor wash, and (3) in the discharge from faucets attached to the condenser intake pumps, were consistent always within 0.25° F., and differed, on the average, but 0.1° F. Reliable results are evidently procurable from the stern, where "surface" observations may, perhaps, most accurately and readily be made in cold windy weather. A record from the condenser intake pipe appears truly representative of the surface temperatures under virtually all conditions.

The condenser intake temperatures recorded by engineers in the engine-room log of the *Empress of Britain* were found to average 0.5° F. above the temperatures accurately obtained in other ways. This difference appears to arise from some heating of the water about the fixed thermometers in the pumps but mostly from errors of parallax in reading. The most serious deficiency in these observations is the absence of a record of the exact time when they were made. Hourly observations on the international ice patrol ships,

Tampa and *Modoc* are apparently of the same order of accuracy as those on the *Empress of Britain*.

In comparison with the surface water temperature obtained with a tin bucket from a lower deck at about the same time, water surface temperatures procured by the author with a canvas bucket dropped from the bridge averaged 0.5° F. too low, and those by quartermasters with the same bucket averaged 1° F. too low. These errors were the combined result of the predip temperature of the canvas bucket, evaporative cooling of the partially filled canvas bucket after leaving the sea, temperature change of the thermometer if withdrawn for reading, and several unsystematic errors, such as occasional 5 or 10 degrees misreadings. On some other ships the average depression of the recorded canvas bucket temperatures below the condenser intake values was found to be 3° F. or more. In the Gulf Stream region north and northeast of Hatteras, winter observations from four ships gave canvas bucket temperatures averaging about 5° F. lower than the condenser intake. In cold gales over the Gulf Stream, departures in a group of 24 observations from 4 ships were so large as to have a median at 7 and upper extremes of 20 to 24° F.

An analysis of some observations made on the ice patrol ships show the same tendencies when the air was much colder than the sea. Thus, Lieut. Commander E. H. Smith's observations of surface temperature stood higher than the usual canvas bucket determination from the bridge by an average of 0.7° F. for cold water (10 cases) and 1.8° F. for warm (13 cases) on and about the Grand Banks.

Errors are closely related to the depression of wet bulb or air temperature below the water temperature. With air temperatures no more than 3° F. below the observed water temperatures the temperatures obtained with the canvas bucket are likely to be more than 1° F. in error in but 15 to 30 per cent of the cases. Water temperatures obtained under lower air temperatures, and especially when wind velocities are high, are likely to be too low by one-third to one-half the depression of the air temperature below the observed water temperature.

With due care, involving the use of dry, stiffened canvas or wooden or fiber buckets dropped from a low deck, heaved up rapidly and as quickly observed, accurate temperatures are obtainable. The use of a thermograph, the thermal element of which projects into the condenser intake pipe, is recommended, however, as much the easiest method for procuring temperatures of the general surface layer accurately under all conditions of weather. Even in late spring and summer, when surface layers are warmed more than those at intake depths, the average difference between the surface and 5 meters depth (16.3 feet) has been found to average but 0.2° C. (0.36° F.). In the 66 observations on which this average was based the surface was 0.5° C. (0.9° F.) or more warmer than water at 5 meters but 12 times, and 1° C. (1.8° F.) or more warmer but three times. The greatest difference observed was 1.52° C. (2.7° F.).

INTRODUCTION

Purpose of observations on merchant ships.—Observations of sea-water temperatures are made every four hours or oftener by the great majority of ocean-going steamships. The objectives are: (1) to obtain indications of currents or the general proximity of ice, (2) to determine the volume of water required for the condenser, and (3) to cooperate in the collection of observations for forecast purposes and for later study. A degree of accuracy giving temperatures within a few degrees Fahrenheit may be satisfactory for immediate purposes of navigation but not for scientific study. This paper attempts to show to what extent water temperatures observed by the usual methods differ from the actual surface temperatures, and by what means the most accurate surface temperature observations may be obtained.

Sea surface temperatures needed for meteorology.—For a study of ocean temperatures in relation to the weather, those of the surface waters are most important. It would seem to be a simple matter to obtain such temperatures, but there are a number of difficulties, beginning

with that of getting a thermometer into truly surface water. From a small boat or canoe at rest in quiet water the temperature may be found simply by inserting the thermometer into the water. On a large boat under such conditions a pail or pipe is required to bring water to the thermometer unless a closed reservoir thermometer or registering thermometer can be used. As soon as water is dipped up, however, its temperature begins to change. In calm weather, if the ship is in motion, surface temperatures can be obtained only from the bow, by some device to test the undisturbed surface.

WATER TEMPERATURE OBSERVATIONS FROM LARGE SHIPS UNDER ORDINARY CONDITIONS

In windy weather, the usual condition at sea, the disturbance created by the boat is little, if any, greater than that made by the waves themselves. So the temperature of water dipped from any position on the ship, or even sucked in from several feet below the surface, is likely to represent the true surface temperature, provided the water so transported does not cool or warm appreciably before its temperature is taken. Under the conditions of turbulence and rapid mixture going on in windy weather, the discharges from a ship rarely have a noticeable effect on the temperature of water forward of the main outlets or in the churned wake of the vessel. Ten sets of nearly simultaneous observations fore and aft were made with a 2 or a 4 quart tin bucket, heaved up rapidly after practically a full catch. Of 42 observations on 10 occasions on 8 days, with wind velocities from Beaufort 2 to 5, 3 showed no difference in temperature fore versus aft; 5 differences of 0.1° F. or less; and 2, differences of 0.2° F.[3] The average difference of but 0.08° F. is only a third greater than the average of the differences between similar successive observations made each time from the same place on the ship. The temperatures aft averaged only 0.04° F. warmer than those forward. This difference can readily be attributed to the cooling of the bucket while it was being heaved up, this cooling being greater on the windswept side of the ship than under the stern. On the only occasion when the wet bulb temperature was the same as the water temperature, five dips, three aft and two forward, were of identically the same temperature.

Advantages of sampling from stern.—In rough weather, especially when the air is appreciably colder than the water, stern hauls appear to have every advantage over the customary (*1*) ship-side hauls forward. (1) The discharges of the ship are so well mixed with the much greater quantities of ocean water that they do not appear to affect the temperature off the stern of a moving ship. It would seem that there would be a greater chance for taking in some discharge water from far forward in putting the bucket over the side from the bridge than in throwing it over the stern. From the stern there are the additional advantages (2) of working facing the bucket, (3) of getting nearer the water, (4) of dealing with less wind, and therefore, (5) of having less evaporative cooling to lower the water temperature in the bucket. In quiet weather, however, especially when air temperatures are well above the water temperatures, such stern hauls are not so likely to represent the slightly warmer surface layer as are dips from near the bow.

COMPARISON OF SURFACE WITH CONDENSER INTAKE TEMPERATURES

Water well mixed by cool winds.—With temperatures in the wake of the ship essentially the same as those forward under all conditions met, it is fair to assume that with rare exceptions, the temperatures are the same to a depth of several feet, at least nearly to the total depth from which the propellors bring water immediately to the surface. On the 11 occasions when 75 comparative observations were made this was found to be the case.[4] These observations were made over a wide range of wind velocity, Beaufort 2 to 8, and water temperatures 79° to 37° F., on 8 days. On all occasions the wet bulb temperature was appreciably (3.5° to 19.2° F.) below the sea temperature. The same thermometer, tested by Mr. S. P. Fergusson of the United States Weather Bureau, was used for all observations.

The surface temperatures were obtained by quick hauls of a tin bucket well filled mostly by dips from the stern. The individual temperatures so obtained were liable to an error of probably not over 0.2° F. owing to cooling in the air (cf. p. 246, below). The condenser intake temperatures were read from the same thermometer squirted with water from the small faucets attached to the three pumps. There were differences between pumps amounting usually to no more than 0.1° or 0.2° F., though once one discharged water 0.3° to 0.4° F. higher than the other two. Evidently, at times, some warming of the water took place in the ship before it was discharged from the faucet where observed. The readings could be made only with a hand light and in an awkward position near the floor. They are thus liable to a slight error of reading, probably about 0.1° F.

The differences between the observed surface and condenser intake temperatures averaged but 0.13° F.; the condenser intake was the warmer by an average of 0.10° F. There were 4 occasions when the intake was about 0.25° F. the warmer, 2 when it was from 0.15° to 0.05° F. the warmer, 3 with no difference, and 1 when the condenser intake appears to have been 0.15° F. the colder. With the observed surface temperatures subject, apparently, only to a negative departure, owing to evaporation while the samples were being hauled up and observed, while the condenser intake temperatures were subject only to a positive departure, owing to warming within the hot ship, it is surprising that the observed intake temperatures were found to average no more than 0.10° F. higher than the surface temperatures. The difference, even in the most extreme instances, about 0.25° F., was so small as to indicate no appreciable difference between sea temperatures at the surface and down to a depth of at least 22 to 24 feet (that of the intake).

Quiet water in summer.—A series of comparative observations in calm weather in water that is being warmed at the surface is required to show whether or not these conclusions will apply under practically all conditions. Calmness, however, is a condition seldom met at sea; therefore, it seems reasonable to accept as a working basis the observed facts, that in general sea temperatures about a ship are essentially the same fore and aft, both at the surface and at the intake depth. (See further discussion p. 243, below.)

[3] A detailed table (I) presenting all data in this comparison has been filed in the Library, U. S. Weather Bureau, Washington, D. C.

[4] For full details a table (II) deposited in the Library, U. S. Weather Bureau, Washington, D. C., may be consulted.

A standard for comparison.—It is evident from the foregoing, that under the conditions discussed, quick hauls with a well-filled tin bucket to a low deck or samples from the condenser intake pumps will give the true surface temperature of the sea to within 0.1° or 0.2° F. This conclusion is based on (1) the considerable quantity of water involved and the shortness of time the filled pail is exposed to the air, (2) the small variation, averaging 0.06° F., between the temperatures of immediately successive hauls, the correspondence (3) between temperatures obtained fore and aft, differing on the average by only 0.08° F., and (4) between those at the surface and at the condenser intake, differing by not more than 0.25° or an average of 0.13° F.

With such "standard" observations it was possible to compare a great many other types of observation made by officers and crew of the R. M. S. *Empress of Britain*. Furthermore, it proved possible to use condenser intake temperatures as a semistandard for a wider field of comparisons not only on this ship but also on others.

CONDENSER INTAKE TEMPERATURES AS RECORDED IN ENGINE-ROOM LOG

Condenser intake temperatures are observed by the engineer in charge once every four-hour watch. Unfortunately, the actual time of observation is not noted, so comparisons with temperatures obtained by other means suffer from lack of simultaneity. This is especially important where in the course of a watch the temperatures of the waters traversed differ greatly. This lack of simultaneity, however, is of little consequence in comparing averages, for a departure one time is likely to be balanced by an opposite one another time. Assuming that the engineers observations were made near the middle of the watch, as my experience in a few instances indicated, 56 comparisons were made between temperatures obtained, on the one hand, by me with a well filled tin bucket at about 6 or 10 a. m., or 2, 6, or 10 p. m., and, on the other hand, the temperatures recorded for each watch by the engineers. The frequency distribution of departures was found to be:

Intake minus tin bucket (°F.)	−5	−2	−1	0	1	2	3	4	5	Total
Number of cases	1	1	5	20	21	6	1	0	1	56

The average of intake minus tin bucket is 0.5° F. If 0.1° F. of this is the real excess of intake over tin-bucket temperatures (see p. 242 above), we have a difference of 0.4° F. to account for. The lack of simultaneity does not appear to be responsible for any. For if the departures or portions of the departures quite evidently due to this cause are eliminated from the table we should have:

Intake minus tin bucket (°F.)	−5	−1	0	1	2	5	Total
Number of cases	1	4	24	20	6	1	56

The average is still 0.5°. The two differences of 5° are probably from the engineers' misreading the thermometer an even 5°. Any other errors, or, rather, coarseness in reading probably also balance.

Curves of successive intake temperatures plotted for parts of the Caribbean region where sea temperatures were rather uniform show once or twice in six observations a deviation of about 1° F. above and below a line of constant temperature at about 0.5° F. above the line of tin bucket temperatures. The recorded observations, thus, are rather consistent and, on the whole, carefully made.

Sources of error in usual condenser intake observations.—The nature of some of the deviations now and then was indicated by some observations made by me on visits to the condenser room. One sample may be cited. When the temperature of the sea surface as observed by several hauls with a tin bucket was 75° F., the thermometers attached to the condenser pumps read 76°, 76°, and 75.5°, approximately, while water squirting from the faucets read 75.2° to 75.3° in two of them and 75.6° in a third. The fixed thermometers were difficult to read accurately. The graduations were not cut on the tubes, the bore was rather large and the scale divisions small so it was scarcely possible to read closer than about a whole degree. The fixed thermometer on each pump was only a foot or two above the level of the floor. In consequence, the parallax of reading was at times 1 degree, and usually plus, for the top of the scale was nearest the floor. It was so on this occasion, the engineer's recorded observation being 77°. As the difference between the fixed thermometer on each pump and the faucet temperature was usually of the order of 0° to 0.3° F. it appears that the intake pump thermometers were accurate within 0.2° F. The greater differences sometimes observed, of the order of 0.5° F. (once 15° F.), must have been owing largely to heating of the water in the pump. But what can we say about 90° F. intake temperatures for late February in the West Indian region found in the log of a British freighter? The canvas-bucket record was about 10° lower.

With an average plus departure of but 0.5° F., and few deviations exceeding 2° F., from the actual surface temperatures, it is evident that the condenser intake temperatures recorded by the engineer officers in charge on the R. M. S. *Empress of Britain* are dependable, and with an average correction of −0.5° F. may be considered in each case as the sea-surface temperature at some point on the ship's course within about 20 or 30 miles of the position of the ship the middle of each watch. If the minute of each observation were noted the value would be greatly increased, since the location could then be determined with some exactness. The worst instance of time "error" noticed was for a 4 to 8 watch when the reading was not made till 7.18, at which time it showed 54° F. A quarter of an hour earlier the temperature was 67°, and at 6 it was 71°.

The hourly condenser intake observations on international ice patrol ships.—Some of the conclusions reached on the *Empress of Britain* are confirmed by an analysis of about 700 pairs of hourly bucket and intake records during 33 days selected at random from the United States Coast Guard international ice patrol ships, *Tampa* and *Modoc*, from April to July, 1925.[5] In tabulating from the typewritten copies of the "smooth" logs, I was struck by the preponderance of changes occurring at every fourth hour, 1, 5, and 9 a. m., and 1, 5, and 9 p. m., or with the beginning of each watch. Grouping the data by hours of the watch I found that, though the percentage of all data showing changes from the previous hour was 31, the percentages by hours were 40, 25, 30, and 30 for the

first to fourth hours (excluding the 12 to 4 a. m. watch, for the first hour of which the change data were not tabulated). It is evident (1) that the new observer each watch reads the thermometer differently from the preceding one, (2) that he either does not look at the thermometer or reads it carelessly the second hour, and (3) that he observes it with reasonable care the third hour and probably the fourth.

The excess of the changes the first hour over those the third hour may be considered a fair indication of the personal equation in reading a thermometer with markings every 2 degrees, for there is no other reason why more changes should occur between watches than within a watch. The average difference of 0.35° F. corresponds exactly to the personal equation for the canvas bucket observations with 2-degree graduation thermometers on the ice patrol boats for the same dates, 0.35° F.

There is a tendency for observers not to catch small changes, and at times, owing to the difficulty of accurate reading, to record changes of one or two degrees. This results in some lack of simultaneity of change of the same sign as the vessel passes through waters of differing temperature. Out of 217 changes noted in intake temperatures but 122 were recorded simultaneously for surface temperatures, and 21 of these were of opposite sign. It is probable that surface and intake temperatures change in the opposite sense simultaneously at times. But nearly twice as many (39 versus 21) simultaneous changes were allotted to the first hour of a watch as to the last hour of the preceding watch. These suggest that, as in the case of the *Empress of Britain* observations, about a sixth of the changes recorded did not really occur at the hour noted.

The systematic errors of parallax appear to be of the same order as those of the *Empress of Britain* but of opposite sign, for on the ice patrol ships the lower figures on the scale are nearest the floor. With the thermometers low down, their tubes well in front of the scale, and observer reading, as Captain Newman says, from the standing position, the temperature will appear lower than it really is. The amount is at least 0.6° F. as shown by comparisons with the corresponding canvas bucket records for the 23 times with wet bulb temperature a degree or more below the intake figure and with wind velocity 4 (night) or 5 (day time) or more Beaufort. Under such conditions, of cooling at the surface with a strong wind blowing, surely the temperatures at intake depths, about 15 feet on these ships, can not differ appreciably from those at the surface. The error due to parallax is more than 0.6° by the amount the canvas bucket observation is affected by evaporational cooling under the circumstances.

THE BUCKET METHOD

The canvas bucket and its use.—The canvas bucket is a means of obtaining samples of water from the surface, but the observed temperatures of such samples may depart widely from the actual temperature of the surface water. The bucket used on the R. M. S. *Empress of Britain* was a cylinder of canvas 14 inches high and 5 inches in diameter, with a base formed by a heavy wooden block about 1 inch thick, and a top rim of ¼-inch rope. The canvas was made tight to the base with the aid of a strip of leather and copper tacks; on the side the canvas overlapped on the seam 1½ inches, and at the top the canvas was doubled back 2 inches for added stiffness. The bucket had a rope handle reaching 7 inches above the rim to the place where the

casting line (small rope about one-fourth inch in diameter) was attached. The bucket was commonly dropped from the bridge, where the log was kept. With the coil of line in hand the bucket was swung well forward on the leeward side of the ship, and allowed to drop into the water. If it failed to make a good catch of water it was hauled up a few feet, swung forward, if possible, and dropped again, then hauled up to the bridge. Once the bucket was set on deck a reservoir thermometer was inserted for a brief period, while the rope was being coiled, then the temperature was read usually to the nearest whole° F. Finally the bucket was tipped on its side to empty the water, the thermometer hung up beside the thermometer screen, and the temperature noted in the log.

This practice conforms approximately to Krümmel's statement of modern methods used (2). These methods, he says, belong to the simplest of the operations which the sailor has to do. Perhaps this is unfortunate, for what is simple is often carelessly done. According to Krümmel a bucket is thrown overboard and after letting it drag a little while or after hauling it up and dumping it and then putting it in again it is hauled aboard and in a shady spot the temperature is determined accurately. Earlier methods in which the temperature was read in the sun made the observations somewhat too high. The use of canvas buckets aboard sailing vessels gives readings too low unless they are taken immediately, for there is considerable evaporation from the outside of the canvas. A good thermometer for the purpose is graduated to the tenths of degrees and the mercury cylinder is such that there is rapid response to temperature changes and that it is easy to read. The practice has remained virtually unchanged since systematic observing was begun in the middle of the Nineteenth century. Maury's instructions in 1851 read: "In taking temperatures of surface water, a fresh bucket should be drawn up each time, the thermometer plunged into it immediately, held there for several minutes, and *read while the bulb is in the water*" (3).

What advantage a canvas bucket enjoys by virtue of its durability, appears to be more than offset by its tendency to collapse and, therefore, not to fill properly. A tin bucket suffers so from banging against the ship's side that it can not be used more than a few hundred times, but it readily makes a full catch of water. Furthermore, the tin bucket quickly dries. A thick paper or fiber bucket, suggested by Dr. H. B. Bigelow (orally) would combine durability, stiffness (for full catches), and quickness in drying.

Departures of canvas-bucket samples from sea-surface temperatures.—On 10 occasions I made comparisons of sea-surface temperatures obtained by the long-haul canvas-bucket method and the short-haul tin bucket, at practically the same time. In all there were 20 individual observations with the canvas bucket and 29 with the tin.[6] In the five cases with a wet bulb depression exceeding 10° F. the canvas bucket sample appears to have averaged 0.6° F. below the sea temperature, there being three cases with departures of 0.8° or 1° F., one of 0.5, and one of −0.1°. In the three instances with wet bulb depressions of 9.6°, 9.5°, and 9.4° F. the departures were 0.7°, 0.5°, and 0.4° F., respectively. In the remaining two, with wet bulb depressions of 2.3° and 1.8° F. the departures were 0.3° and 0.1° F. There is evidently a connection between the depression of the wet bulb and the cooling of the canvas bucket, the cooling in the course of an observation lasting about one minute being

[6] A detailed table (III) is on deposit in the Library, U. S. Weather Bureau, Washington, D. C.

about 5 to 10 per cent of the depression of the sling wet bulb below the sea temperature. Whether the cooling will be nearer the 5 or the 10 per cent appears to depend on the wind velocity, the larger departures going with wind velocities of Beaufort 5 or more, relative to the ship. In these comparisons the temperatures in the canvas buckets were observed immediately after they were landed, the same quickly responding cylindrical bulb thermometer being used, as for the observations in the tin bucket. Corresponding observations made by quartermasters with the ship's spherical bulb thermometer were lower in cool windy weather by about 0.5° to 1° F. owing to the longer exposure before reading. My direct comparison, therefore, does not show departures of canvas bucket temperatures from the sea temperatures as large as those given by the usual, less immediate readings by the quartermasters. Three other comparisons were made, involving the quartermasters' regular observations, on the one hand, and tin bucket temperatures, second dip temperatures, or condenser intake temperatures, on the other.

Temperatures obtained by quartermasters with canvas bucket.—Using as a basis for comparison 79 sets of observations with a well-filled tin bucket hauled up from one of the lower decks at times within 15 minuets of the scheduled hour of observation with the canvas bucket, and when it appears the water temperatures themselves were not changing rapidly, as many as 23 of the 79 hauls of the canvas bucket differed from the apparent water temperature by 2 to 7° F. Half of these important departures occurred north of latitude 35° during cold winds, in fact, 12 of the 14 comparisons made in these latitudes deviated by 2° F. or more:

Depression of canvas below tin bucket temperatures (°F)	-2	-1	0	1	2	3	4	5	6	7	Total cases
Observation latitude 35° and north	0	0	1	1	1	5	3	1	1	1	14
Observation between latitudes 35° and 9°	2	8	22	23	9	0	1	0	0	0	65
Total	2	8	23	24	10	5	4	1	1	1	[1] 79

[1] For more detailed treatment, see below.

The average was 10° F. lower temperature for the canvas bucket observations than for those by the tin bucket.

¶Another set of 24 observations in which the pail temperatures were obtained in the course of oceanographic soundings by Lieut. Commander Edward H. Smith, have been kindly submitted by him. These observations were made on the international ice patrol ships *Tampa* and *Modoc* in the Grand Banks region from April 26 to June 29, 1926.

The average depression of the surface temperature obtained by bucket from the bridge is 1.4° F., but for the warmer water 1.8. These are to be compared with 1.0 for all and 3.4 for the 14 cases in the northern zone in the wintertime table above. Even in the warmer months the evaporational errors of the usual bucket observations are considerable.

Depression of bridge bucket below pail temperatures (°F.)	-15	-4	-1.1 to -0.1	0.1 to 1.1	1.2 to 2	4.1 and 4.5	5.5 and 7.4	Average
Observation in cold water (32–44)	1	1		2	2	3	2		[1] 0.9
Observation in warm water (49–64)			3	5	2	1	2	1.8

[1] The -15 case omitted.

Sources of error in the bucket method.—In the course of an observation with any type of bucket there are numerous influences tending to make the final record depart from the actual surface temperature: (1) The bucket is not likely to have the same initial temperature as the sea surface; (2) the water sample being hauled up is usually cooled by evaporation; (3) the thermometer inserted is seldom at the same temperature as the water in the bucket; and (4) while it is resting in the bucket further cooling, or perhaps heating, of the water may take place; (5) when the thermometer is read it may not have reached the temperature of the water in which it is immersed; and (6) if it is withdrawn, to be read more easily, the temperature of the very small sample in the reservoir may change before the temperature is observed; furthermore (7) after the markings and numbers have become indistinct errors of reading creep in, and it is easy to see the same temperature as at the last reading, (8) the thermometer itself may be inaccurate, and (9) there is a slight chance that the quartermaster may forget what the reading was by the time he gets to the log book, and simply repeat the preceding figure. Of course, many of these sources of error are usually negligible, but the total effect is not infrequently a departure of several degrees Fahrenheit from what appears to be the true surface temperature. Some attempt will now be made to specify and evaluate these.

Predip temperature of the canvas bucket.—The canvas bucket itself is usually at a different temperature from the sea. If the bucket were always dry and of low heat capacity and if the samples obtained were full buckets, this temperature of the bucket would be of little consequence. Often, however, the bucket can not dry between one observation and the next. Even when there is no spray flying over the ship, some time is required to dry out the thick wet canvas, rope, leather, and wood, particularly since some residue of water usually remains when the bucket is emptied. When the bucket is wet, its temperature approaches that of the wet bulb, as is shown in the following four cases. The figures show temperature depressions of the objects specified below sea temperatures obtained with tin bucket:

Case No.	Sling wet bulb	Wet bulb in shelter on bridge (behind weatherboard)	Residue of water in canvas bucket	
	Cooler than the sea	Cooler than the sea	Cooler than sea	Time since last dip in sea
	°F.	°F.	°F.	Hours
1	22	18	16	½
2	12	10.5	10	1¼
3	11.5	10	8	¾–1
4	11.3	8	7.7	1¾–1

[1] One-fifth of a bucketfull.

In case 4 the cool bucket, when heaved over about one-fifth full of residual water 7.7° F. cooler than the sea, brought up a sample 1.8° F. cooler than that of a second casting immediately after. With the use of a dry bucket, at about 4° F. below the sea temperature, however, at another time, a first dip brought up a sample 0.1° F. warmer than a short tin bucket haul on the opposite (windy) side of the ship. A wet bucket warmed in the sun to 2° F. above the sea temperature brought up two samples of the same temperature, probably the true sea temperature. It seems evident, therefore, that a canvas bucket should be dry or, if wet, at about the

temperature of the sea water before it is used. Perhaps a regular practice could be made of hanging the bucket upside down at the top of one of the outlet ventilators. While this might make the bucket too warm, it would be dry and its heat capacity small, and its extra warmth would usually tend to offset the cooling by evaporation as the sample was being hauled up. Differences between first and second hauls with a canvas bucket, including the effects of the predip temperature of the canvas bucket were found from 14 pairs of my own observations to be as follows:

	Second bucket the cooler by—			Second same temperature as first	Second bucket the warmer by—					
°F	0.7	0.2	0.1		0.3	0.4	0.5	0.9	1.7	1.8
Cases	1	1	2	4	1	1	1	1	1	1

The number of seconds warmer than firsts were 6, versus 4 cooler, while the average of seconds is 0.3° F. higher than that of the firsts.

After noting the apparent effect of a cool bucket on the temperature of the sea surface sample, the officers and quartermasters kindly cooperated in obtaining temperatures by double dips each hour while at sea. Usually the bucket was still wet from the hour previous, and being in an exposed position near the rail its temperature was probably generally below that of the sea surface. While reasonable care was exercised in the observing, the temperatures were not often noted closer than the nearest half or whole degree Fahrenheit. Furthermore, with two values to record, some errors were occasioned by the observers not recording either temperature till both had been obtained. From some checks, however, these deviations do not appear to have been serious. The 262 pairs of observations showed the following distribution of differences:

	Second bucket the cooler by—					Second same temperature as first	Second bucket the warmer by—				
°F	1.0	0.5	0.4	0.3	0.2		0.2	0.3	0.5	0.8	1.0
Cases	4	21	2	5	3	187	1	1	35	2	1

The results were disappointing—the effect of the original temperatures of the bucket became almost submerged in the longer period of general cooling of the wet bucket after it left the sea, and in the less detailed reading of the thermometer. Since only 4 of my 14 comparisons showed no difference, it seems that perhaps half of the 187 of the quartermasters' cases of no recorded difference were in reality differences of a few tenths of a degree.

The averages of the recorded temperatures of the first and second dips differ by 0.14° F., the second bucket being the warmer. This is half the average difference in my 14 comparisons. This small difference shows that practically nothing is to be gained in eliminating the effects of a cool bucket by having quartermasters make two consecutive dips when the throw is from so high as the bridge, the action of the observers not very fast, and, therefore, the wet bucket so exposed as nearly to return to a wet bulb temperature between dips. The numerous cases of the second dips cooler than the first may indicate lower evaporative temperatures of thoroughly wet buckets than those of partly dried ones.

Since we are considering errors arising from evaporation, these must show some relation to the depression of the wet bulb thermometer and perhaps to the wind velocity relative to the ship. If the bucket is still wet from the previous hour, the greater the evaporation the more the temperatures of two successive buckets of the new observation should tend to depart from one another. The averages here given, including as they do, so many zero differences, are very small—perhaps insignificantly so; nevertheless, there is no break in their progressive increase with atmospheric dryness or wind velocity.

Sling wet bulb below sea temperature, °F	0 to 3	4 to 6	7 to 9	10 to 13	0 to 13
Average difference between first and second dips, °F	0.090	0.145	0.154	0.210	0.14
Cases	48	114	70	30	262

Screen wet bulb below sea temperature, °F	−2 to +1	2 to 3	4 to 5	6 to 7	8 to 12	−2 to 12
Average difference between first and second dips, °F	0.100	0.136	0.141	0.153	0.176	0.14
Cases	20	61	102	49	30	262

Wind velocity (Beaufort) relative to ship	0 to 3	4 to 5	6 to 9	0 to 9
Average difference between first and second dips, °F	0.13	0.14	0.16	0.14
Cases	74	98	90	262

Cooling of canvas bucket from the time it leaves the sea till the temperature is observed.—Though the observed difference between a first and second dip with a canvas bucket at no time was greater than 1.8° F., and but few times was as much as 1° F., the depression of the water temperature observed in the canvas bucket below that obtained more accurately by other means was usually 1° F. or more. The cooling of the bucket after it leaves the sea evidently adds a further depression of temperature that usually equals or exceeds that already caused by a bucket cool on entering the water. Even a full bucket was observed to cool 1° F. in three minutes on deck in a moderate wind with the sling wet bulb at 22° below the water temperature. A number of direct comparisons of observations with a canvas bucket under different weather conditions with those made with a tin bucket at practically the same time have already been referred to (p. 245, above). Other less immediate and less definite comparisons will be found below. Unfortunately, I made no observations with the ship's canvas bucket from low in the stern to discover to what extent the evaporative cooling could be reduced by getting full buckets and hauling them up but a short distance more or less out of the wind. As a substitute, I can offer a series of observations with tin buckets. The well-filled tin buckets showed the small variability, between immediately successive hauls, of less than 0.1° F., already referred to. Canvas buckets, however, with a greater surface relative to weight of water and with a more persistent wetness than the tin buckets might have shown slightly less consistent results than did the tin buckets.

Cooling of tin buckets of sea water in quick hauls.—During a fresh gale over the Gulf Stream between Bermuda and New York, March 22, 1924, I made 67 observations with a 4-quart tin bucket from 10 to 20 feet above the sea on the leeward stern. The wet bulb was 14°–25° F. below the sea temperature. With each haul the approxi-

mate fullness of the bucket and the quickness of the haul was noted and tabulated, and the following conclusions reached from a comparison of the temperatures obtained at intervals of one or two minutes. (a) One-third to one-half pails of water would be cooled usually one-third to two-thirds of a degree Fahrenheit more than full pails were, before the temperature could be taken, while (b) one-fifth to one-eighth pails would be cooled generally 1° to 2° F. in the same time, about a minute, usually less; (c) in quick hauls taking one-third to one-half minute the loss in temperature would be but 0.1° or 0.2° F., even for one-fifth of a bucket. At the same time the temperatures obtained from the bridge by quartermasters averaged 3.5° F. lower—evidently owing to the cooling in the longer exposure to the stronger wind along the side of the ship.

Minor sources of error in canvas-bucket method.—Three other minor sources of error not always operative, though at times very large, are the cooling of the water by the thermometer, the cooling of the thermometer if withdrawn for reading, errors in reading or recording, and inexactness in the time of observation. The coolness of the thermometer before it is plunged into the water may account at times for a few tenths of a degree lowering of the temperature of a poorly filled bucket. If the thermometer is of the reservoir type, and especially if it retains a little cool water from the last observation, the small amount of water that comes into contact with the bulb may be cooler than the general body of water in the bucket. The thermometer is usually stirred but little, if at all. Withdrawing it from the water for reading almost always introduces errors. A reservoir thermometer, with full reservoir, exposed to a moderate wind with a wet bulb depression of 22° below the initial water temperature cooled 6° F. in 3 minutes. A nonreservoir thermometer cools much more, —5° F. being that described by Dr. James as the common depression found in some night observations in the Caribbean region in summer. The quartermaster, he said, took the thermometer from the bucket to a light for reading. Even such a demonstration as getting the quartermaster to wave his wet hand and feel the cooling did not induce him to change his practice.

Actual errors in reading are not often of consequence, and, usually being large, are rather easily discovered. In the *Empress of Britain* observations an error of just 5°, 10°, or 15° F. occurred, apparently, about once in 100 times. Such errors always were at night and are not to be wondered at, in view of the difficulty of keeping thermometer markings readily legible when they are so frequently wet with sea water. One of the most interesting pairs of errors in reading or noting came just after the *Empress of Britain* crossed the "cold wall" from the Gulf Stream. At 7 p. m. the temperature recorded was 67°, at 8 it was 66.5°, though in the meantime the sea temperature had fallen to 54°. It seems likely that in the cold gale the bucket sample had a temperature of about 52°, 15° below the entry. Sixty-one degrees was the record at 9, and 51° at 10. The quartermasters appear to have been loath to believe their eyes. On the score of thermometer errors, Helland-Hansen and Nansen say that 30 to 50 per cent of the thermometers used are bad. (4)

When observations are required hourly, as on the ice patrol ships, on the Grand Banks there is a decided tendency for the observations at the second and fourth hours of a watch to repeat those at the first and third hours. In a selection from the typed records for about 30 days, scattered from April to July, 1925, of the ice patrol 48 per cent of the observations in the first hour were different from those of the last hour of the preceding watch, 29 per cent the second hour, 35 per cent the third hour, and 21 per cent the fourth hour. These correspond fairly well to the 40, 25, 30, and 30, for intake temperatures mentioned above. Twice as many changes at 5 and 9 a. m., and 1, 5, and 9 p. m. as at 8 a. m., noon, 4, and 8 p. m. and midnight surely did not occur. In the excess of changes for the first hour of each watch is included, of course, the personal difference in reading a thermometer, which appears to average 0.35° F. for readings to 1° made on a 2° thermometer.

Finally, inexactness in the time of observation is an error to be contended with. Usually a difference of a few minutes from the recorded time of observation is of no consequence, but at times it may mean a difference of 10°, 20° F. or more in actual sea surface temperature. The quartermasters' observations made "on the hour" varied from about 20 minutes before to 10 minutes after, with no note made of the deviations.

Comparative evaluation of errors from canvas-bucket observation.—With the total average and some extreme deviations known, it is possible roughly to divide the total error among the several causes. The initial coolness of the bucket when wet, as usual, seems to have accounted for 0.2° F. and the further cooling of the bucket while being hauled up, for 0.3° F. of the 0.5° F. average difference found when quickly observed temperatures in the canvas bucket were compared with those of the tin bucket. (See p. 245, above.) An additional evaporative cooling of 0.2° F. seems to have taken place on the average before the quartermasters got the temperature, while cooling by or of the thermometer, the average error in reading and from inexactness in time of observation, each perhaps 0.1° F., make up 0.5° F. additional, bringing the total depression of the quartermasters' observations to an average of 1° F. below the sea temperature. (See p. 245, above.)

Some comparisons of canvas bucket with condenser intake temperatures are interesting in connection with the frequencies of different sizes of errors and the averages for different wind and wet bulb conditions. One striking fact is that while the quartermasters on the *Empress of Britain* lost only 3° to 4° F. from the surface water temperature, the observers on the S. S. *Fort Victoria*,[1] in the same sort of severe weather, commonly lost over 10°, and several times 20°, the extreme being 24° F. This difference and the comparisons made with observations of the S. S. *San Lorenzo*,[1] and the R. M. S. P. *Orca*[1] appear to indicate that the observers on the *Empress of Britain* were more careful than most.

Depressions of canvas-bucket temperatures as functions largely of evaporative cooling.—In the following tabular summaries is presented the relation between the apparent cooling of canvas buckets below tin-bucket or condenser intake temperatures and the depression of the wet-bulb temperature and the wind velocity. It will be noted that the departures are (1) distinctly a function of the wet-bulb or air temperature depression below the water temperature and (2) less obviously, if at all, related to wind velocity, (3) that the departures are different on different ships, and (4) that on all ships cited the usual departures are greatest in the Gulf Stream region east and northeast of Hatteras.

Comparisons of the 79 canvas-bucket temperatures were made with the nearly simultaneous tin-bucket

temperatures on the *Empress of Britain* (see p. 245, above), according to depression of the sling wet bulb and the wind velocity relative to the ship.

Depression of sling wet bulb below tin-bucket temperature		0 to 5		5 to 10		10 to 15		15+		0 to 15+	
		Average	Cases	Average	Cases	Average	Cases	Average	Cases	Average	Cases
		°F.		°F.		°F.		°F.		°F.	
Wind velocity (Beaufort) relative to ship.	7 to 9	−0.5	6	.....	0	1.9	10	3.2	5	1.7	21
	4 to 6	−0.4	10	0.8	17	1.3	9	1.5	2	0.65	38
	0 to 3	0.0	4	0.2	5	1.7	9	3.0	2	1.2	20
Averages	0 to 9	−0.35		0.59		1.68		2.8		0.99	
Cases			20		22		28		9		79

The values in the table, representing the average of the quartermasters' recorded canvas-bucket temperatures subtracted from my tin-bucket temperatures, show larger depressions with the larger wet-bulb depressions and with the larger wind velocities. Only with wet-bulb depressions below 10° F. were the errors of the canvas-bucket observations under 1° F.

If the condenser intake temperature is used instead of tin-bucket temperature as the basis of comparison, much the same results are obtained, though the departures are greater, owing to the addition of the several sources of error to which the condenser intake observations are subject. (See p. 243, above.)

Depression of sling wet bulb below probable true surface temperature		0 to 5 (average °F.)	5 to 10 (average °F.)	10 to 15 (average °F.)	15+ (average °F.)	0 to 15+ (average °F.)
Wind velocity (Beaufort) relative to ship	7 to 9	1	2	1	9.5	2.3
	4 to 6	0.8	1.2	1.6	2	1.2
	0 to 3	0.8	2.3	5.2	7	3.1
Averages	0 to 9	0.8	1.4	2.3	7	2.0
Cases		11	25	20	4	60

The values in the table indicate the average depression of the recorded canvas-bucket temperature at hours 2, 6, 10, etc., below those of the condenser intake each watch (centered on 2, 6, 10, etc.).

For comparison with observations available from other ships, the summaries of the *Empress of Britain* data must also be stated in terms (1) of air temperature instead of wet-bulb temperature (not available) below the sea temperature, (2) of sea temperature as indicated by the condenser intake instead of by the more exact tin-bucket method, and (3) of actual wind velocity as estimated, instead of that relative to the ship. In spite of these three approximations to more desirable values, the tabulations based on them reflect the major features of the more exact comparisons just given. Here I can present the observations from the January to February, 1924, as well as from the February to March, 1924, West Indies cruise of the *Empress of Britain.* The routes of the two were essentially the same. Data from the February to March, 1924, West Indies cruise of the R. M. S. *Orca*, and from the March, 1924, round trip of the S. S. *San Lorenzo* from New York to Porto Rico, are likewise given.

Canvas bucket below condenser intake temperatures, R. M. S. "Empress of Britain," West Indies cruise

FEBRUARY-MARCH, 1924

Depression of air temperature in screen below condenser intake		Ocean colder than air: −4 to −1		Ocean warmer than air								All	
				0 to 4		5 to 9		10 to 14		15 to 25+		−4 to 25+	
		Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases
Wind velocity (Beaufort)	7 to 9.		0	2.7	3	5.3	3	2.5	2	....	0	3.5	8
	4 to 6.	0.7	3	0.7	36	3.4	10	6	1	5.0	2	1.8	53
	0 to 3.	−0.6	3	0.9	29	2.2	6	10	1	9	1	1.4	40
	0 to 9.	0.1	6	0.8	68	3.7	19	5.3	4	6.0	4	1.8	101

JANUARY-FEBRUARY, 1924

(This cruise was warmer and less windy than the February-March one)

Wind velocity (Beaufort)		−4 to −1 Average °F.	Cases	0 to 4 Average °F.	Cases	5 to 9 Average °F.	Cases	10 to 14 Average °F.	Cases	15 to 25+ Average °F.	Cases	−4 to 25+ Average °F.	Cases
	7 to 9.		0		0	4.5	2		0		0	4.5	2
	4 to 6.	−1.2	6	0.7	32	3.0	14	4.3	6	3.5	2	1.5	60
	0 to 3.	−1.3	6	1.0	32	2.4	11	3.0	2		0	1.2	51
	0 to 9.	−1.2	12	0.9	64	3.0	27	4.0	8	3.5	2	1.4	113

SUMMARY

	−4 to −1 Average °F.	Cases	0 to 4 Average °F.	Cases	5 to 9 Average °F.	Cases	10 to 14 Average °F.	Cases	15 to 25+ Average °F.	Cases	−4 to 25+ Average °F.	Cases
February-March cruise	0.1	6	0.8	68	3.7	19	5.3	4	6.0	4	1.8	101
January-February cruise	−1.2	12	0.9	64	3.0	27	4.0	8	3.5	2	1.4	113

Class	−4 to −2 Average °F.	Cases	−1 to 1 Average °F.	Cases	2 to 4 Average °F.	Cases	5 to 9 Average °F.	Cases	10 to 14 Average °F.	Cases	15 to 25+ Average °F.	Cases	−4 to 25+ Average °F.	Cases
Both cruises	−0.2	9	0.1	65	1.5	76	3.3	46	4.2	12	5.2	6	1.6	214

R. M. S. P. "Orca" February–March, 1924, West Indies cruise and S. S. "San Lorenzo" March, 1924, New York to Porto Rico and return

Depression of air temperature in screen below condenser intake (°F.)	Ocean colder than air				Ocean warmer than air								All	
	−10 to −6		−5 to −1		0 to 4		5 to 9		10 to 14		15 to 20		−10 to 25	
	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases	Average °F.	Cases
Orca	−0.2	5	−4.6	5	−3.7	12	0	5	2.5	2	1.3	4	−1.7	33
San Lorenzo	0	2	1	2	−3.4	18	4.3	15	4.2	5	7.4	5	3.1	47

Something seems to be the matter with the *Orca* temperatures. Possibly the trouble is with the condenser intake observations, for it seems unlikely that the canvas bucket observations should average nearly 2° F. above the condenser intake. The *San Lorenzo* observations are consistent with those of the *Empress of Britain.* The higher general average, 3.1° F. versus the 1.6° F. intake

minus canvas bucket, is due to the fewer observations in tropical waters. Half of the *Empress of Britain* observations were made in waters south of the latitude of Porto Rico.

Canvas-bucket observations in the Gulf Stream region.— From the standpoint of the weather in eastern North America, one of the most important regions of the ocean is that portion of the Gulf Stream east and northeast of Hatteras. It is highly desirable to know accurately what the temperatures of these warm waters are, especially in winter. To what extent, therefore, are canvas bucket

observations made in this region during the severest weather to be relied on? From the tables, the data for this portion of the Atlantic were selected, covering 4 crossings of the Gulf Stream by the *Empress of Britain*, 2 by the *Orca*, 2 by the *San Lorenzo*, and 5 by the *Fort Victoria*.

As a background, the following tabulation of frequencies of different departures of canvas bucket from condenser intake temperatures is presented for the two West Indies cruises of the *Empress of Britain*. (Cf. p. 248.)

Condenser intake each watch minus canvas bucket at middle hour (°F.)	Bucket warmer than intake						Bucket cooler than intake											Total
	−13	−4	−3	−2	−1	0	1	2	3	4	5	6	7	8	9	10	
Jan. 22–Feb. 20, 1924	0	1	3	6	13	18	29	14	15	2	4	1	1	5	0	1	113
Feb. 23–Mar. 23, 1924	1	2	1	1	9	16	29	16	13	3	2	5	1	0	1	1	101
Total, both cruises	1	3	4	7	22	34	58	30	28	5	6	6	2	5	1	2	214

In the Gulf Stream region east and northeast of Hatteras the following are the frequencies of the depressions of canvas bucket below intake temperatures:

Condenser intake each watch minus canvas bucket at middle hour (°F.)	Bucket warmer than intake							Bucket cooler than intake																		Total
	−13	−7	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	20	21	22	24	
Empress of Britain	1			1		1	1	2	2	6	3	2	2	3	2	3	1	1											31
Orca		1		2			1	1			1	1		1															8
San Lorenzo						1	1				3	1		3		1				2									12
Fort Victoria			1		1	2		1		3	1	2	1	3	2	3		2	1			2	2	1	1	1	1	1	32
Total	1	1	1	3	1	4	2	5	2	9	5	5	5	9	4	7	1	3	1	2		2	2	1	1	1	1	1	83
Total by threes	1		2			8			9			22			18			11			3			5			3	1	83

These occurrences may be classified according to coolness of the air relative to the water and according to wind velocity:

Canvas-bucket compared with condenser-intake temperatures

Air temperatures below condenser intake (° F.)	Bucket warmer than intake (° F.)					Bucket cooler than intake (° F.)													
	−13	−7	−6, −5	−4, −3	−2, −1	0, 1	2, 3	4, 5	6, 7	8, 9	10, 11	12, 13	14, 15	16, 17	18, 19	20, 21	22, 23	24
25+									1							m 1	1	1
20 to 24						2	1	1	m 1	m 1				1		1		
15 to 19							3	3	m 2	3	2		2	4				
10 to 14					2	2	2	2	m 8	1	2							
5 to 9	1		1		2	1	m 7	5	1									
0 to 4				3	m 2	1	1	1										
−1				m 1														
WIND VELOCITY																		
Beaufort:																		
9 to 10							1		2	1	m 1		1	1			1	
7 to 8		1				1	3		m			2		3		2		1
4 to 6				2	2	5	5	m 9	6	4		1						
0 to 3			1	2	4	1	m 5	2	5	3	1							

m Stands for median.

Both for depression of air temperature below water temperature and for wind velocity there is a well defined slant to the tables. The median (*m*) is without exception among lower and lower canvas-bucket depressions with lower and lower air-temperature depressions and wind velocities. But since the stronger winds were also the colder ones, as shown in the table below, the effect of wind velocity *per se* is not established by this table. There is usually enough wind about a ship to provide nearly the maximum rate of evaporation possible under the coincident saturation deficit. Averaging the de-

pressions of the canvas-bucket temperatures below condenser-intake temperatures by depression of the air temperature below the water temperature we have, finally, the following:

Depression of air temperature in screen below condenser intake temperature (°F.)	Air warmer −1	Air cooler than ocean					All: −1 to 25+
		0 to 4	5 to 9	10 to 14	15 to 19	20 to 25	
Average (°F.)	−3	−1.9	2.2	4.6	7.3	9.4	4.3
Cases	1	9	19	20	19	15	83

From these tabulations it is evident that canvas-bucket temperatures in the northern Gulf Stream region are not reliable in the cool windy weather so common in winter. On the whole, it seems that if the air temperature is 5° F. or more below the surface water temperature as shown by the condenser intake the canvas-bucket temperature is likely to be well over 1° F. too low. With depressions of air temperature of 5° to 15° F. all wind velocities, canvas-bucket data averaged 2° to 6° F. too low for the warmer waters of the southwestern Atlantic in winter.

Canvas-bucket observations on the ice patrol.—A wider range on the negative side is provided in the following table from ice patrol data in the Grand Banks region in spring and summer, which show what may be expected under conditions of wet-bulb temperatures usually above sea temperatures. The condenser intake values, taken as standard, averaged 1° F. below the canvas-bucket temperatures, so when the wet bulb was the same temperature as the intake is was probably 1° F. below the sea surface temperature. The following table shows the average depression of canvas bucket below intake temperatures for the wet bulb depressions and wind velocities specified. With two exceptions all values are negative, indicating that canvas-bucket temperatures are prevailingly above intake temperatures, the latter, however, being systematically 0.6° F. or more too low.

Departures of condenser intake from canvas-bucket temperatures, °F., U. S. S. "Tampa" (international ice patrol), April–July, 1925, Grand Banks region

Depression of wet bulb in screen below condenser intake temperature (°F.)	Ocean colder than air				Ocean warmer than air				−10 to 22					
	−10 to −3		−2 to −1		0 to 6		7 to 22		Day		Night		All	
	Average °F.	Observations	Average °F.	Observations	Average °F.	Observations	Average °F.	Observations	Average °F.	Observations	Average °F.	Observations	Average °F.	Observations
Wind velocity (Beaufort) 7	0	1	−1.0	1	.....	0	.....	0	−0.5	2	.....	0	−0.5	2
4–6	−2.0	26	−0.4	16	−0.6	37	3.0	3	−1.2	48	−0.4	34	−0.9	82
0–3	−2.0	50	−1.4	28	−0.2	49	−1.0	8	−1.2	63	−1.2	72	−1.2	135
0–7	−2.0	77	−1.0	45	−0.3	86	0.1	11	−1.2	.....	−0.9	106	−1.0	219
Corrected for parallax	−1.4	.....	−0.4	.....	+0.3	.....	0.7	.....	−0.6	113	−0.3	.....	−0.4	.....

Stated in general terms, this table shows surface waters warmer than those at a moderate depth only when the wet bulb temperature is higher than that of the ocean, the average being 1.4° F. when the wet bulb temperature is considerably the higher, and 0.4° when it is but slightly the warmer. For all the data the surface averages 0.4° F. warmer than intake levels. Such variations as there are with wind velocity show a decrease in the excess of surface temperature over intake temperature with increase in velocity. This naturally is to be expected through better mixing of the water by waves, even if there were no effect of the wind on the temperatures of the canvas bucket samples. But evaporational cooling evidently takes place. Forty of the 113 daytime observations and 39 of the 106 nighttime observations showed lower canvas bucket than intake temperatures. Fifty-five per cent of these 40 in the daytime and 80 per cent of the 39 in the night attended wet bulb temperatures equal to or below the intake temperatures. Without exception, the 9 cases of canvas bucket 3° or more cooler than intake

were with wet bulb below condenser intake temperatures. The most extreme instance, not included in the above, was a canvas bucket record of 53° F. while intake was 60° and wet bulb 41°.

Thus, as in the case of the other groups of observations studied in warmer waters during the colder season, errors of evaporational cooling enter into a sizeable percentage of the canvas bucket records obtained from a cold water region in the warmer season, and appear in the averages for observations made when wet bulb temperatures were low.

PRACTICABLE METHODS FOR ACCURATELY OBSERVING SEA SURFACE TEMPERATURES

Now arises the question as to the best and most practicable method of observing the temperature of the general surface layer of the sea. Two have been discussed: (1) The generally used bucket method, and (2) condenser intake observations. A third may be mentioned—the difficult trailing of the thermal element of a thermograph. Of these it appears that the condenser intake offers the best possibility for consistently reliable temperatures, while certain changes in the usual method of handling a canvas bucket for surface temperatures can probably lead to better results. Especial care is required in the northern Gulf Stream region to minimize the occurrence of errors of the order of 5° to 20° F. or more.

Notwithstanding the large errors to which the canvas bucket method is subject, ocean temperatures can be accurately obtained with a canvas bucket, or, better still, a heavy paper, fiber or wooden bucket, if the following precautions are taken: (1) Use dry bucket, or at least empty all residual water before a throw; (2) obtain full bucket of water (use lead sinker and stiffenings in canvas bucket to prevent collapse); (3) make the dips from low deck and haul up fast; (4) protect bucket from the wind during haul, and especially after it is landed, e. g., by heaving over leeward stern in cold windy weather; (5) stir the water with a quick thermometer without obstructing reservoir, and, within a small fraction of a minute, as soon as it becomes nearly stationary, read it as closely as possible; (6) if the haul was not a full and quick one, or if the bucket was rather exposed to the wind after wetting, repeat at once; (7) record the minute of each observation, which is as important as the nearest tenth or half degree of temperature. Such specifications presumably require the immediate supervision of all hauls by the officers in charge of the meteorological observations.

The condenser intake offers probably the most satisfactory opportunity for obtaining accurate temperatures of the stirred surface layer of the ocean. The engineers' observations (*Empress of Britain*) average within 0.5° F. of the apparent true temperatures, and rarely deviate as much as 2° F. from what appear to be the actual temperatures. Since many deviations and perhaps portions of most appear to be due to occasional pockets, or locally reduced circulation about the fixed thermometers in the pumps, errors on this score may be avoided by placing thermometers in the intake pipe between the intake and the pumps. Recording apparatus may readily be installed in this position if a continuous record is desired.

Conclusion.—Briefly stated, we need to do two things: (1) insure the collection of accurate water temperature data in the future, by installing thermographs and by encouraging observers to guard against the sources of

error besetting their methods [3] (1), and (2) make the best of the great body of data already gathered, not discarding it because beset with numerous errors, but using it with a discrimination begot of an understanding of its limits of accuracy.

DISCUSSION

The discussion after the paper (American Meteorological Society, January, 1925), turned mostly on the best means for obtaining water-surface temperatures at sea. The first question was pointed: "If it seems so easy to take intake temperatures, why do you take temperatures from the side?" Dr. S. J. Mauchley said the canvas bucket was a relic from sailing days, and Prof. R. DeC. Ward added that such observations were continued for that reason.

Obtaining accurate data.—Speaking from considerable experience Professor Ward told of the difficulties of getting men to be accurate who are not interested and who do not want to take the observations. Ordinarily, he said, the ship officers do not care enough about the work to do it.

Prof. C. F. Marvin thought the time was coming when doubtless one could get far more accurate and more abundant water temperatures from ships at sea, and he asked how accurate such observations should be and how they should be obtained. The best you can expect the average seaman to do is to read to the nearest whole line. He will not bother about the fractions of a degree. Doctor Brooks replied that the nearest whole degree (F.) should be close enough, though he would not want to have the observer make an error and then use the nearest whole degree.

Dr. V. Bjerknes, emphasized the importance of reading to the nearest half degree (C)., and showed that in making adequate synoptic maps at sea the equatorial and the polar air streams were to be identified by their air temperatures relative to the water surface temperatures. If the air were 15° C. and the water 14.5° C. one would be dealing with the equatorial air stream, while if the air were 15° C. and the water 15.5° C. one would have the polar air stream. An observer who was not particular would be likely to report air and water temperatures the same in both instances. Doctor Bjerknes said that on the Norwegian ships the radio men do the observing, and that under conditions of frequent inspection, encouragement and a salary good results were being obtained.

Sea-temperature thermographs in the Pacific.—Mr. J. Patterson, in response to a question from Mr. Calvert told in detail how the Canadian Meteorological Service was obtaining accurate records of temperatures in the North Pacific, thanks to the installation of thermographs attached to the condenser intake pipes of some Canadian Pacific liners.

Mr. Patterson expressed himself as agreeably surprised at the close correspondence Doctor Brooks had found between condenser intake and surface temperatures. He had thought the temperature difference much greater. This difference would be most pronounced on warm sunny days, when one would expect the surface layer to be appreciably warmer than those at a depth of 20 or 30 feet, but evidently the mixing is very complete to that depth and consequently an accurate record of

sea water temperature can be obtained at the condenser intake.

Remarking on observers, Mr. Patterson called attention to the fact that the engineers do not have close contact with the officers on the bridge and that in consequence the men in each set go about their observations in their own way and do not take much cognizance of each other's observations. The engineers are chiefly interested in the efficiency of the condensers and this is given by the difference in temperature between the water entering and leaving the condensers. If required to take a special set of observations it means extra work for them for something in which they are not interested and they can hardly be blamed if the work is done in a haphazard way. A platinum thermometer with a potential indicator was tried out on one of the boats. By turning a wheel the instrument could be read to 0.1° F., but the observers had all sorts of trouble with it and did not get satisfactory results. The wires broke or the insulation went bad and it was not a success.

Mr. Patterson found that the engineers like the recording thermometers, as the chart has to be changed only once a week and the record is always in view. It has explained some things they could not understand before. The best thermographs have a range of 50° F. on a 3-inch scale, from about 35° to 85° F.; this range will cover all the temperatures experienced in the North Pacific. The thermal element is a large bulb filled with mercury and connected by fine capillary, 8, 10 or 12 feet long as required, to a Bourdon tube compensated; while the accuracy may not be consistently up to the manufacturers claim of 0.1° F., these instruments are reliable within 1° F. A change of 40° or 50° in temperature of the capillary would not affect the readings by 0.1° F. Since the bulb is of steel it is necessary to put it into a copper well inserted in the intake of the condenser so as to protect the bulb from corrosion. The bulb cannot be replaced if once damaged, but if the outer tube is destroyed by the sea water it can easily be replaced. The records show that the ordinary fluctuations from hour to hour are very slight, only about a degree in a whole day, but on the edge of the Japanese Current there is a very rapid variation, even in the course of an hour or two; in the current itself there is always considerable variation.

Experimental work on the Grand Banks.—Mr. Eaton described a durable electrical resistance thermometer devised at the Bureau of Standards for aircraft. With unpainted bridge and constant voltage the accuracy is within 0.5° F.

Dr. H. C. Dickinson told of some means of measuring sea temperatures he had devised about 12 years ago. He used a sounding mechanism that gave a continuous record of temperature, accurate to about 0.01°. The point was to detect any relation between water temperature and near-by icebergs. A platinum resistance thermometer was used in the intake and another in a thin flat sheet against the outer shell of the ship. Still a third was trailed behind on the surface, but it got involved with the propellor. These methods of recording can be made fairly satisfactory, but the equipment is rather expensive, and it would require occasional overhauling, perhaps at the end of each trip.

Temperature differences found at sea.—At about latitude 40° in the western Atlantic, as much as 20° F. difference in temperature was found in the length of the ship, said Doctor Dickinson. There were warm masses one-fourth to one-half mile wide. The record in traversing these is an irregular curve (5). Professor Ward mentioned an instance of 30° F. difference between bow and stern.

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[3] U. S. Weather Bureau, "Instructions to marine meteorological observers," Circ. M, 4th ed., Jan., 1925, devotes a whole page (14–15) to a summary of the larger sources of error discussed in this paper, calls attention to the importance of sea surface temperature data, and encourages observers "to exercise their best judgment and skill in making these observations."

Mr. Patterson, replying to a question by Prof. Milham, said that the annual range of temperature in the coldest part of the ship lane across the North Pacific was of the order of 15° F. from January to August, while the difference between one month and the next might be 4° F. In the Japanese Current the variations were even more. Mapping and averaging the temperatures by 5° squares presents difficulties when the Japanese Current is included in part of a square. The ships in the lane, however, are in this current for only a day; and as the lane never varies more than 50 or 100 miles across, the Pacific region from which data are obtainable is in consequence very limited in extent. It is perhaps interesting to know that ships from San Francisco traverse practically the same course as those from Vancouver.

Are condenser intake temperatures always representative of surface temperatures?—The discussion of the paper concluded with Dr. W. J. Humphreys objecting to the use of condenser intake temperatures as representing the surface in quiet sunny weather, since it is the actual surface temperature that affects the air temperature and the actual surface that discharges the moisture into the air. While admitting this, Doctor Brooks pointed out, however, that appreciable differences between surface and condenser intake levels observable by usual methods must be rare.

THE CASE FOR CONDENSER INTAKE THERMOGRAPHS [9]

Do condenser intake temperatures, accurately obtainable by thermograph, always fairly represent surface temperatures as well as do canvas bucket observations? In other words, how well do canvas bucket temperatures represent the true water surface temperatures; and what differences in temperature occur between the surface and a depth, say, of 5 meters? Mr. H. W. Harvey (6), believes the usual dip with canvas bucket represents the top 6 inches of water, and not the true surface layer of occasional high temperature. Prof. James Johnstone, referring to bucket observations, says: "By 'surface' is meant the stratum of water to a depth of about a foot" (7). U. S. Weather Bureau instructions, in force till 1925, called for water "drawn from a depth of 3 feet below the surface" (8). Canvas bucket observations, as shown in detail above, are usually subject to errors due to evaporation, while large unsystematic errors occasionally enter.

The temperature of the surface rarely differs greatly from that at a depth of 5 meters. In winter and early spring the average difference found was but 0.1° F. In calm clear weather in August, however, Mr. Harvey says the surface temperature of the English Channel 20 miles southwest of Plymouth sometimes reaches 19° C., though the general body of the surface layer has a temperature of 14° to 15° C. in that month (6). The most extreme case of surface heating mentioned was an excess of 1.5° C. at a depth of half an inch over that at 8 inches. A bucket, however, can not fill with the warm thin surface sheet unmixed. Thirty-eight observations of surface temperatures (wooden bucket) with those at 5 meters depth were kindly furnished in manuscript by Mr. Harvey. They were made during the warmer months, May to September, 1921 to 1925, at the western end of the English Channel. On the average, the surface was 0.32° C. warmer than the water 5 meters below. Fourteen of the 38 had a difference of 0.1° C. or less; 21 of the

38 were within 0.2° C.; 10 differed by 0.5° or more, and 3, by 1° or more, the extreme being 1.52° C. These differences are somewhat less than the diurnal range of surface temperature (9). Mr. Harvey's observations show that the well-mixed surface layer of relatively warm water is usually 12 to 20 meters thick (6).

Some figures picked at random by Dr. H. B. Bigelow from his oceanographic notebooks show a similar small difference in the Gulf of Maine region. In May, 1920, and August, 1922, the average of four surface temperatures was 0.33° C. warmer than the corresponding temperatures at 5, 9, or 10 meters depth. The individual differences were 0.1°, 0.2°, 0.3°, and 0.7° C. Harvey's and Bigelow's observations show that in midlatitudes in summer, condenser intake temperatures should average about 0.3° C., or not more than 0.6° F., below the surface temperature, and that differences of 0.5° to 1.5° C (0.9° to 2.7° F.) are to be expected a quarter of the time.

Three series of less direct observations substantiate this conclusion. On the line from New York to Trinidad in mid-August, 1924, 38 bucket observations by Dr. P. E. James averaged 0.4° F. higher than the intake temperatures, while the bucket observations by the quartermasters averaged below the intake temperatures. Nighttime bucket observations by Doctor James were the same as the intake ones in temperature, as were also those on windy, cloudy days. During a hurricane, however, his canvas bucket observations were, for a time, 1° to 2° F. lower than the condenser intake values. Afternoon surface temperatures on fair days were 1° or 2° F. above the condenser intake temperatures.

On the S. S. *Meline*, crossing the Atlantic in latitudes 53° to 41° N., late in June, 1922, but 12 of the 40 observations (four hourly) showed bucket warmer than intake; 8 of these were 1° warmer and 4 were 2° F. warmer. The average of all 40 was bucket 0.1° F. cooler than intake.

Perhaps as great a contrast between surface and intake temperatures as is to be found anywhere should be expected in the Grand Banks region in spring and summer. The international ice patrol ships, *Tampa* and *Modoc* keep an hourly record of bucket and intake sea temperatures. A selection of 345 pairs of these observations was made from the typewritten copies of the logs of these ships for 26 to 30 days, April to July, 1925, on file in the Washington office of the United States Coast Guard. At odd-numbered hours—those when the observations seemed most carefully made—the averages of canvas bucket minus condenser intake after the latter was corrected 0.6° F. for error of parallax (which made the readings too low, were as follows:

	Hours, a. m.						Hours, p. m.					
	1	3	5	7	9	11	1	3	5	7	9	11
°F	-0.2	0	-0.1	0.6	0.6	0.6	1.1	0.5	1	0.9	0.3	0.1

Throughout the 24 hours the surface temperatures averaged from 0.2° F. below to 1.1° F. above those at intake depth, about 15 feet. The average of the daytime hours, taken as 7 a. m. to 5 p. m. was 0.7° F., and of the nighttime hours, 0.3, and of all the data 0.5° F.

To afford more certain comparisons Lieut. Commander Edward H. Smith kindly made 24 observations of sea temperatures at the surface and 5 meters depth and submitted the corresponding bridge and engine room determinations. These were from April 26 to June 29,

1926, on the *Modoc* and *Tampa* in the Grand Banks region. The average difference between surface and 5 meters down was but 0.02° C. (0.04° F.), the surface being the cooler. In 23 of the 24 observations the difference did not exceed 0.2° C., in the other it was 0.8° C. (1.4° F.) the warmer on the surface. The surface was slightly warmer than at 5 meters 6 times, the same temperature 7, and cooler 11. The corresponding temperatures obtained from the bridge and the condenser intake in the engine room differed an average of 0.2° F., the surface being the cooler. One pair of the 24 was omitted in making this average, for the two differed by 15°, evidently owing to lack of simultaneity of the observations as the ship crossed a boundary between warm and cool water. Four other pairs differed 5° F. or more. The 23 comparable surface reports averaged 1.4° F. lower than Commander Smith's observations, a difference probably owing largely to evaporational cooling, for the 13 cases of warm water averaged 1.8, and the 10 of cool water 0.9. The engine room temperatures averaged 1.1° F. lower than observed temperatures at 5 meters depth, divergence which appears to be due largely to parallax in reading. Thus, the fairly close correspondence between surface and intake temperatures as observed regularly on the bridge and in the engine room is in this small group not significant.

Altogether, these several sets of observations from different regions are fairly consistent indications (1) that the average summer time difference between the surface and intake depths is of the order of 0.6° F. or less, the 66 oceanographic observations averaging 0.4, (2) that in only a quarter or less of the time in summer will the surface layer be 1 or 2° F. warmer than intake levels, and (3) that departures of more than 2° F. are rare.

Conclusion.—The case for condenser intake thermographs rests on the following points in their favor: (1) They have much greater accuracy than the canvas bucket method usually employed; (2) they show true surface temperatures in winter and in windy weather anytime; and (3) their indications in summer will differ from surface temperatures by no more than 0 to 0.6° F. on the average, not over 2° F. oftener than once in 40 to 60 times. The thermograph's accuracy in winter is to be compared with an average depression of 1° F. found for canvas bucket observations in this season; and its 0 to 0.6° F. "inaccuracy" in summer is to be compared with equal if not greater ones in the same direction found in the usual bucket observations. Bucket observations *can* be made accurately, but they commonly are not; a thermograph trace is more dependable.

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  See (*2*) above, p. 382–385.

COMMENT

By F. G. TINGLEY

Doctor Brooks has performed a valuable service in investigating the methods whereby the temperature of the surface sea water is obtained. Meteorologists have always assigned to the oceans such an important part in the scheme of weather causation that anything bearing on the subject of their temperature is always welcomed. The present article forms an important contribution to the technique of ocean temperature observations and any one reading the account of Doctor Brooks's experience on board the *Empress of Britain* will gain a very clear idea of the conditions under which such observations are made and the hazard of error to which they are subject. Moreover, they will doubtless gain a better appreciation of the esteem in which such observational material is held by meteorologists. Observers on board ship, especially, should realize the high value that is placed on their work.

The cruise of the *Empress of Britain* afforded an opportunity to study the making of surface-water temperature observations under almost every condition met by observers. Beginning at New York in February, under winter conditions, the course of the vessel lay southward across the Gulf Stream, through waters of different origin and varying temperatures, to the Tropics, where summer conditions and uniform surface temperatures prevailed. That Doctor Brooks took full advantage of his opportunities is attested by the wealth of detail that characterizes the paper.

The outstanding fact he discloses is the large element of error apparent in observations made by the canvas bucket method in the region between New York and Bermuda. On this is based his argument for using intake temperatures instead of those taken by canvas bucket. At first sight the case against the bucket appears rather serious, but investigation of the large amount of data collected by the Weather Bureau through the cooperation of vessel masters and other officers leads to the belief that the rather numerous and, in some cases, large errors reported by Doctor Brooks were exceptional. In the compilation of water temperature data it is generally possible to detect erroneous readings where the error is large. Small errors, including those due to lack of calibration of thermometers and those coming under the head of personal equation may be depended upon to offset one another in any considerable body of data.

The purposes of Doctor Brooks's investigation and of the Weather Bureau's were somewhat different. Doctor Brooks's was the two-fold one of emphasizing the value of water temperature observations and of calling attention to the importance of using every precaution to insure the highest attainable accuracy in their making. The bureau's object has been not so much to determine the absolute temperature of the sea water as to establish

the degree of accuracy with which the data show its *changes* of temperature. The data have been subjected to various forms of analysis which need not be described here. As a result, it is felt that they are entirely adequate to show the changes that are taking place in any region in which the areal distribution of temperature is fairly uniform and the disposition of the observations reasonably constant. A region like that between New York and Bermuda must, however, be excepted, on account of the great mixture of warm and cold waters found there. Probably no single group of observations, such for instance as those taken by all vessels crossing

the region in a given month, could be depended upon to give the true mean surface temperature of such a region as a whole, even though the individual observations were highly accurate. Even continuous records of temperatures, obtained by means of sea water thermographs, might not suffice for more than the ships' courses in these regions of exceptional temperature range. The Weather Bureau has recently installed such an instrument on a vessel plying between New York and Porto Rico and it hopes that the data which will soon be available will shed further light on this important subject.

RECENT INVESTIGATIONS ON THE ENERGY IN THE EARTH'S ATMOSPHERE, ITS TRANSFORMATION AND DISSIPATION

By Edgar W. Woolard

In the physical system of the earth's atmosphere, we find numerous forms of energy displayed on a gigantic scale; and transformations from one form to another are continually taking place (1). Kinetic energy, in particular, is constantly being dissipated—transformed by friction and turbulence into heat which is ultimately radiated away—and hence a continuous supply of energy must be available to maintain the ceaseless activity of the atmosphere against the action of the resisting influences. The only available adequate source of all except an infinitesimal amount of atmospheric energy is ultimately the solar radiation which is intercepted by the earth (2). The atmosphere acts like a gigantic heat-engine, transforming radiant energy from the sun into the energy of atmospheric phenomena; and the general problem of meteorology consists of elucidating the details of the mechanism and the processes by which, under the usual laws of dynamics and thermodynamics, this energy results in the production and maintenance of the sequence of atmospheric phenomena, these phenomena collectively making up the continual activity in the atmosphere, and involving the changes in the daily distribution of the meteorological elements that provide the daily weather for every part of the globe (3).

From the approximately known mass (4) of, and mean wind velocities in, the earth's atmosphere, Brunt (5) concludes that the total *kinetic* energy of the *general* or *planetary* circulation is of the order of 3×10^{27} ergs; considerable additional kinetic energy is frequently developed in storms, as Shaw has pointed out (6). The equations of motion show that the rate of dissipation of kinetic energy due to the virtual internal friction introduced by turbulence is equal to the product of the pressure gradient into the component of wind velocity in the direction of that gradient. In steady motion along an isobar (frictionless gradient wind) there is no dissipation, but if, due to turbulence, there exists any motion across an isobar into lower pressure, there is a dissipation; and a steady motion can be maintained only if energy is supplied at a rate equal to the product of velocity of inflow and gradient (5).

The theory of the variation of wind velocity with height, produced by turbulence, makes possible an integration which shows that the total loss of energy due to turbulence in a column extending from the surface to the limit of the atmosphere is practically equal to the loss in the column extending from the surface to that height (about one kilometer) at which gradient direction is first attained, consequently the dissipation of energy by turbulence is, as we might expect, effectively restricted to the layer below this height (5). At greater heights, the changes of wind with elevation are deter-

mined, not by turbulence produced at the ground, but by the horizontal distribution of temperature; and the rate of loss of energy must be determined in a different way (7).

Neglecting the dissipation above 10 kilometers, Brunt finds, finally, for the rate of loss of kinetic energy above one square meter of the earth's surface (5): From surface to 1 kilometer, 3×10^{-3} kw./m.²; from 1 to 10 kilometers, 2×10^{-3} kw./m.²

If the rate of dissipation be assumed proportional to the energy remaining, the kinetic energy of the general circulation would be reduced to 0.1 its value in three days. This loss must be made up by the conversion of solar energy into kinetic energy of winds. After allowance is made for the earth's albedo of 37 per cent, the remaining 67 per cent which constitutes the effective incoming solar radiation (i. e., that which is absorbed, and in some way used up in the production of weather phenomena, before being again returned to space) is found to average for the whole earth 0.22 kw./m.²; the conversion of a little over 2 per cent of this into the particular form of kinetic energy of winds in the planetary circulation would make up for the continual dissipation of the latter[1] (5).

No completely satisfactory and universally acceptable theory has yet been put forward, however, which explains the details of the mechanism of the continuous dynamic and thermodynamic process by which solar energy is converted into atmospheric energy. The major actuating cause of atmospheric activity is undoubtedly the unequal heating and cooling in different latitudes. This sets up temperature differences that in turn set up pressure differences, and lead to a planetary circulation involving interzonal exchange of air by way of the cyclones, anticyclones, and other secondary phenomena which come into existence in the temperate zone. The highly complicated and irregular circulations thus set up are, however, far from being completely understood or accounted for.

If we regard the phenomena exhibited by separate masses of air, we have little difficulty in finding evidence of all the separate stages of the thermal cycle of a heat-engine (8). A thermodynamic engine must operate between two different temperatures. The "boiler" of the atmospheric engine is that part of the land and sea warmed above the temperature of the overlying air by

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[1] The cross section of the solar beam constantly being intercepted by the earth is πR^2. R=radius of earth; averaging the energy in this beam over the entire surface of the earth, and taking the solar constant to be 2 g. cal. per cm.² per min., we find that if the solar energy were spread uniformly over the whole earth at all times, each square centimeter would continually receive $2 \frac{\pi R^2}{4\pi R^2} = .5$ g. cal. /min.; considering .37 of this to be reflected and scattered to space without ever taking any part in the thermodynamic processes of the atmosphere, we are left with .315 g. cal. per cm.² per min., or .22 kw./m.² for the effective incoming energy; 2 per cent of this is 4.4×10^{-3} kw./m.², while the total dissipation is 5×10^{-3} kw./m.².

solar radiation, together with those parts of the atmosphere which are warmed directly by solar radiation; such conditions are particularly marked in tropical regions The "condenser" is any part of the surface of land or sea colder than the air above it, and any part of the atmosphere which is, in the net, losing heat by radiation; these conditions are most effectively present in the vast cooling surfaces of the arctic and antarctic regions. The atmosphere as a whole does no useful work—the atmospheric engine has an efficiency zero—for most of the work done is turned into heat by friction and turbulence in the air and the ocean, and ultimately radiated away. Hence in the long run there is a balance between incoming effective solar radiation and outgoing earth radiation; this necessarily follows from the fact that no part of the earth is continuously increasing or decreasing in temperature. Since in the long run the total thermal effect is immeasurably small, the solar energy which passes through the atmosphere merely maintaining the *status quo ante*, we can not deal with the relation between heat and work by regarding the whole atmosphere as a unit. The dynamical effects attributed to the heating by solar radiation combined with the cooling by earth radiation are dependent upon the differential treatment of separate parts of the atmosphere; we must therefore suppose a portion of air to be isolated, and trace the thermal changes which it undergoes.

Until comparatively recently, the manner in which the atmospheric engine works seemed to present little difficulty: The general circulation was considered to be the direct consequence of ascent of warm air at the equator and descent of cold air at the poles, there being a permanent circulation from equator to poles in the upper atmosphere, with a return flow in the surface or middle layers. Similarly, cyclones were considered to form in regions where the air was warmer than the surrounding air, with a consequent upward motion of the warm air through its colder environment; and the anticyclone was considered to be a region of cold descending air (9). However, we now know that the atmosphere is thermally stratified and hence normally restrains large-scale vertical circulations, that there is no direct and regular exchange of air between polar and equatorial regions either at the surface or aloft, that some cyclones are relatively cold and some anticyclones relatively warm; and we recognize many puzzling phenomena in connection with ordinary thermal convection. We are thus called upon profoundly to modify many of our simple conceptions and to solve many new problems (9).

Probably most of the radiant energy from the sun is first converted into some form of potential energy which is subsequently released in the form of kinetic energy, very little solar energy being converted directly into the kinetic form. The well-known mechanism of conversion suggested by Margules (10) however, is considered by Brunt to be more applicable to thunderstorms and line squalls than to the general circulation. The transfer-

ence of solar energy into kinetic energy may in part be brought about through the ascent of warm humid air within the Tropics, the ascended air moving poleward aloft, but being able to descend in middle latitudes in spite of the thermal stratification on account of cooling by radiation. It completes a cycle by moving equatorward over the surface (11); the amount of work done in the course of such a cycle has been computed by Shaw (12). Certainly the abundant rains of the doldrums (and other regions) are definite evidence that convection is operative in the atmosphere on a large scale; and the ascent of the relatively small quantity of 100 cubic kilometers of air per second to 15 kilometers, this air drifting north, cooling by radiation, descending in latitude 60°, and returning equatorward, would contribute just enough kinetic energy to the general circulation to replace the energy dissipated by turbulence. The descent of cold air over the slopes of Greenland and the Antarctic continent would also contribute some energy, but the computations of L. F. Richardson indicate that the amount so contributed can be only a very small fraction of that dissipated (5).

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CONFERENCE OF THE INTERNATIONAL COMMISSION ON SOLAR RADIATION AT DAVOS AUGUST 31 TO SEPTEMBER 2, 1925 [1]

By H. H. KIMBALL

There were present at the conference the following persons, who were, except the last named, members of the commission: Messrs. J. Maurer, the president; A. Ångström, Stockholm; C. Dorno, Davos; L. Gorczyński, Warsaw; H. Hergesell, Lindenberg; Chr. A. Nell, The Hague; C. Schoute, de Bilt; R. Süring, Potsdam; and F. Linke, Frankfort.

Sessions were held on the morning and the afternoon of August 31 and on the mornings of September 1 and 2.

The following were nominated for membership on the Commission: Messrs. Åkerblom, Upsala; Linke, Frankfort; Moll, The Hague; and Volochine, Prague.

Among the important questions considered were the following:

(1) The founding of a Central Institute for Solar Radiation.

(2) Questions of the first importance in solar radiation (standardization of pyrheliometers, transmission coeffi-

cients of filters, study of photo-electric cells, study of diffuse radiation and of radiation to the sky, study of ultra-violet radiation, etc.).

(3) The solar constant. The commission expressed its admiration for the important and fruitful work of Doctor Abbot on the measurement of solar radiation and hoped that the means which have been placed at his disposal would permit him to continue his researches at high altitudes with much uccess.

(4) The view was expressed that it is exclusively for the permanent Meteorological Commission to decide upon the relation which should exist between this commission and that of section (c), International Union of Geodesy and Geophysics.

(5) M. Ångström reported on the researches at the observatory of Stockholm, and spoke on the possibility of predicting temperature changes from actinometric measurements.

(6) The question of establishing a publication for actinometric observations and studies was discussed. It was decided to invite "reporters" to summarize for the different countries matters pertaining to actinometry.

The following were designated as "reporters": For Germany, R. Süring; for Poland, Ed. Stenz; for Holland and Belgium, C. Schoute; for the Scandinavian countries, A. Ångström; for America, H. H. Kimball; for France, C. Maurain; for England, W. H. Dines; for Russia, N. N. Kalitin; for Italy, L. Palazzo; for the Iberian Peninsula, F. M. Costa di Lobo; for Australia, E. F. Pigot.

The following resolutions were adopted by the commission:

Resolution I: The commission resolved to address propositions to different institutes asking them to take up certain important actinometric investigations, and decided also to submit to the chiefs of these institutes special recommendations relating thereto.

Resolution II: In consideration of the great importance of the compensation method of K. Ångström, which ought to be used for standardization in actinometric measurements, the International Radiation Commission asks that the Meteorological Hydrographical office at Stockholm and the Physical Institute of the University of Upsala undertake a detailed investigation of the possible sources of error in the instruments concerned and make a report thereon to the president of the commission.

Resolution III: The International Radiation Commission considers it highly important that suitable filters be available for isolating parts of the total radiation in pyrheliometric measurements throughout the range of the solar spectrum and that arrangements be recommended for testing such filters. The commission begs the Netherlands Meteorological Institute (in collaboration with the Physical Institute of the University of Utrecht) and the Meteorological-Geophysical Institute at Frankfort on the Main to undertake these important works.

Resolution IV: The International Radiation Commission considers it highly desirable that the pyrheliometer of K. Ångström, which was accepted at the meeting at Innsbruck as the standard instrument, be compared with an absolute instrument constructed according to an independent principle and asks the Meteorological Institute at Potsdam (in collaboration with the Physikalisch-Technische Reichsanstalt, Charlottenburg) to consider this question. It is important also that the question as regards the construction of an absolute standard, to be used only for standardizations, be considered, and the commission hopes the institute will attend to this question also.

Resolution V: The International Radiation Commission expresses the special wish that in all countries where scientific researches are pursued or will be pursued at stations for airplane flights the possibilities of making radiation measurements in airplanes will also be studied.

The commission is at present not able to recommend special instruments for the purpose, but asks that reports on the present status of work in this field be communicated to the president of the commission.

Resolution VI: The International Radiation Commission expresses the following wish:

It is very desirable that the spectro-pyrheliometric measurements be extended to different regions of Europe and especially to the mountain regions, which at present as regards such investigations are represented by Davos alone.

The commission will especially support the proposal that studies of the spectral distribution of solar radiation be extended to the Carpathian Mountains, to the Scandinavian Mountains and to the Brocken, and also to the mountains situated on the Mediterranean coast. The commission requests the president to put himself in communication with the meteorological institutes concerned in order to realize this project.

The preceding resolutions were signed by J. Maurer, Zurich, president; A. Ångström, Stockholm; L. Gorczyński, Warsaw; F. Linke, Frankfort; C. Schoute, de Bilt; C. Dorno, Davos; H. Hergesell, Lindenberg; Chr. A. Nell, The Hague; R. Süring, Potsdam.

Davos, at the Observatory of Dorno, September 2, 1925.

ALASKA'S MILD WINTER OF 1925-26

By H. J. THOMPSON

[U. S. Weather Bureau, Juneau, Alaska]

Alaska, with an area of approximately 590,884 square miles, experienced the mildest winter in the history of Alaskan weather records, particularly so over the southeastern portion and the upper Yukon Valley. It must be borne in mind that the weather records in Alaska are not very old as compared with the stations in the States. On account of Alaska's shifting population and the slow means of communication from the remote parts, it is difficult to obtain long and continuous records from many localities of the Territory. There are, however, some long and accurate records for representative sections of Alaska. Sitka, in the southeastern portion, and one of the oldest permanent settlements in Alaska,

has the longest weather records in the Territory, there being 44 years of temperature and 58 years of precipitation data. Most of the other stations have records averaging from 5 to 25 years.

Although November and December, 1925, and February and March, 1926, were very mild, special emphasis is laid on the phenomenally mild midwinter month, January, which is normally the coldest month of the year. This January, however, was the warmest on record throughout the Territory, except at Barrow, St. Michael, the Aleutian Islands, and the coast sections of the Seward Peninsula, where a few Januarys have averaged slightly higher. The January mean temperature

for the entire Territory was 22.2°, or 14.0° above the average and 2.1° warmer than a normal November. The greatest excess over the previous high records for January in various sections was over the central portion of the interior, where the temperature averaged from 10° to 19° above the previous records. Over the upper Yukon Valley the excess was from 2° to 8°, and over southeastern Alaska, 4° to 8°.

The accompanying table shows the monthly mean temperatures with the departures from the normals from November 1, 1925, to March 31, 1926, for selected stations in Alaska, western Canada, and several northern States.

TABLE 1.—*Monthly mean temperatures with departures from the normals for the winter of 1925–26* [1]

Station	Length of record, years	Nov.	Dept.	Dec.	Dept.	Jan.	Dept.	Feb.	Dept.	Mar.	Dept.	Means	Dept.
Fortmann Hatchery	22	40.6	+3.2	40.1	+8.5	40.6	+14.7	37.8	+7.5	43.6	+8.8	40.5	+8.5
Juneau	30	40.4	+5.1	38.2	+7.0	39.6	+12.8	35.0	+5.2	40.8	+7.3	38.8	+7.5
Ketchikan	15	41.8	+2.8	42.4	+6.3	41.2	+10.9	[3]37.8	+4.1	[3]41.1	+4.7	40.9	+5.8
Prince Rupert, British Columbia	18	42.4	+2.0	43.5	+7.2	43.0	+10.2	[3]40.7	+4.7	[3]44.4	+6.0	42.8	+6.0
Sitka	44	42.3	+3.7	42.8	+7.4	43.2	+11.4	[3]39.2	+5.1	[3]43.8	+7.2	42.3	+5.0
Skagway	21	37.2	+5.1	33.9	+8.2	37.6	+18.3	31.1	+5.6	40.8	+11.1	36.1	+9.7
Wrangell	11	41.0	+3.0	40.6	+9.7	41.2	+14.2	[3]36.0	+4.7	41.6	+8.6	40.1	+8.0
Means		40.8	+3.6	40.2	+7.8	40.9	+13.2	36.8	+5.3	42.3	+7.7	40.2	+7.2
Cordova	14	38.0	+4.3	32.5	+4.0	38.3	+12.6	30.6	+0.6	39.0	+7.1	35.7	+5.7
Katalla	4	37.9		35.0		38.4		31.4		38.4		36.2	
Kodiak	27	37.3	+2.4	29.0	−1.5	36.6	+7.7	32.4	+1.3	[3]38.2	+4.6	34.7	+2.9
Latouche	9	39.6	+3.4	33.7	+2.8	38.4	+9.9	32.8	+0.9	38.4	+5.5	36.6	+4.5
Valdez	17	31.8	+5.1	23.8	+4.5	31.7	+14.2	19.4	−2.0	32.9	+8.3	27.9	+6.0
Means		36.9	+3.8	30.8	+2.4	36.7	+11.1	29.3	+0.2	37.4	+6.4	34.2	+4.8
Kennecott	12	22.6	+8.8	10.8	+7.7	21.4	+18.1	5.6	−5.6	30.2	+14.7	18.1	+8.7
Means		22.6	+8.8	10.8	+7.7	21.4	+18.1	5.6	+5.6	30.2	+14.7	18.1	+8.7
Matanuska	9	32.2	+10.6	11.6	+1.8	30.0	+21.7	19.8	+2.5	38.8	+16.4	26.5	+10.6
Talkeetna	8	28.5	+7.9	8.6	+0.1	26.4	+21.3	12.8	+3.4	33.4	+13.1	21.9	+7.8
Means		30.4	+9.2	10.1	+1.0	28.2	+21.5	16.3	−0.4	36.1	+14.8	24.2	+9.2
Bethel	3	19.8		7.0		15.8		4.8		26.5		14.8	
Means		19.8		7.0		15.8		4.8		26.5		14.8	
Dutch Harbor	27	36.4	+1.2	31.0	−1.5	33.8	+4.0	30.4	−0.4	35.2	−0.5	33.4	+0.6
Means		36.4	+1.2	31.0	−1.5	33.8	+4.0	30.4	−0.4	35.2	−0.5	33.4	+0.6
Dillingham	12	25.2	+1.0	11.9	−2.4	28.2	+14.8	17.6	+3.1	30.7	+8.3	22.7	+5.0
Nome	19	20.0	+4.6	5.8	0.0	[3]9.8	+9.2	−2.4	−7.9	20.8	+11.7	10.8	+3.5
St. Michael	21	21.2	+5.3	4.0	−1.2	11.8	+6.6	−0.4	−2.9	19.6	+9.9	11.2	+3.5
St. Paul Island	15	35.4	+2.7	27.9	+0.4	28.4	+6.0	21.8	−0.2	27.8	+2.0	28.3	+2.2
Means		25.4	+3.4	12.4	−0.8	19.5	+9.2	9.2	−2.0	24.7	+8.0	18.2	+3.6
Allakaket	16	0.2	+8.5	−19.5	−0.9	2.6	+26.0	−16.7	−5.5	[4]10.4	+13.2	−4.6	+8.3
Dawson, Yukon Territory	25	10.4	+8.8	−5.2	+7.8	7.2	+29.6	−6.8	+5.2				
Eagle	26	11.0	+7.9	−4.2	+7.3	12.2	+27.9	−3.7	+0.7	[3]22.9	+15.1	7.6	+11.8
Fairbanks	22	8.6	+5.8	−5.9	+1.5	12.6	+27.0	−2.4	−1.8	26.8	+16.5	7.9	+9.8
Fort Yukon	12	1.1	+7.6	−12.2	+10.0	−3.0	+22.9	−12.2	+3.7	[3]12.4	+12.6	−2.8	+11.4
Holy Cross	23	15.2	+4.7	−0.4	+1.4	11.7	+15.3	−0.1	−3.5	[3]25.9	+12.7	10.5	+6.1
Rampart	22	4.4	+5.6	−8.0	+4.8	5.4	+24.5	−5.7	+1.7	[4]14.5	+9.6	2.1	+9.2
Tanana	25	5.6	+6.2	−11.0	+0.4	9.8	+25.1	−6.0	−1.1	[3]19.4	+13.3	3.6	+8.8
Means		7.1	+6.9	−8.3	+4.0	7.3	+24.8	−6.7	−0.1	18.9	+13.3	3.5	+9.3
Barrow	14	−5.5	−5.0	−15.4	−0.6	−14.0	+6.0	−20.6	−4.9	−12.7	+1.3	−13.6	−0.6
Candle	15	9.5	+4.3	−8.6	−5.0	[3]−2.2	+8.0	−16.0	−10.7				
Noorvik	8	7.8	+4.0	−5.3	−1.0	4.5	+16.3	−15.4	−9.4	13.2	+11.5	1.0	+4.3
Means		3.9	+1.1	−9.8	−2.2	−3.9	+10.1	−17.3	−8.3	0.2	+6.4	−6.3	+1.8
Means for the entire Territory		24.8	+4.7	13.8	+2.2	22.2	+14.0	12.0	−1.4	27.9	+7.9	20.1	+5.6
Means for the coldest winter, 1917–18		13.9	−6.2	−1.2	−12.8	10.6	+2.4	11.5	−1.9	14.8	−5.2	9.8	−4.7

MEAN MONTHLY TEMPERATURES FOR SELECTED CANADIAN STATIONS

Station		Nov.	Dept.	Dec.	Dept.	Jan.	Dept.	Feb.	Dept.	Mar.	Dept.	Means	Dept.
Barkerville, British Columbia		26.6	+3.0	28.6	+7.7	25.7	+7.9	26.6	+7.7	31.6	+5.5	27.8	+6.4
Battleford, Saskatchewan		24.1	+7.8	15.8	+10.4	15.3	+21.4	15.3	+15.2	24.7	+11.6	19.1	+13.3
Calgary, Alberta		29.4	+3.6	31.5	+13.3	29.2	+20.8	28.2	+14.7	34.9	+8.7	30.6	+12.2
Edmonton, Alberta		23.9	+1.0	20.4	+7.3	20.6	+18.8	19.4	+11.1	30.3	+6.1	22.9	+8.9
Kamloops, British Columbia		35.7	+2.3	35.7	+6.8	28.8	+5.8	37.4	+9.1	44.6	+8.5	36.4	+6.5
Le Pas, Manitoba		24.7		6.1		1.0		6.5		11.6		10.0	
Medicine Hat, Alberta		32.6	+5.2	26.9	+8.7	24.6	+19.1	27.8	+16.6	36.7	+9.2	29.7	+11.8
Minnedosa, Manitoba		22.6	+5.3	12.0	+6.3	9.5	+16.7	12.7	+15.4	17.3	+4.8	14.8	+9.7
Moose Jaw, Saskatchewan		27.8		17.9		18.5		20.8		27.4		22.5	
Prince Albert, Saskatchewan		21.4	+6.0	12.7	+9.9	11.6	+20.0	15.8	+18.8	21.4	+9.4	16.6	+12.8

COMPARATIVE MONTHLY MEAN TEMPERATURES FOR ALASKA AND FOR SELECTED STATES FROM NOVEMBER, 1925, TO MARCH, 1926, INCLUSIVE

Station		Nov.	Dept.	Dec.	Dept.	Jan.	Dept.	Feb.	Dept.	Mar.	Dept.	Means	Dept.
Alaska		24.8	+4.7	13.8	+2.2	22.2	+14.0	12.0	−1.4	27.9	+7.9	20.1	+5.6
Michigan		34.7	−1.5	23.7	−1.2	22.0	+2.1	22.2	+3.8	23.9	−5.0	25.3	−0.4
Minnesota		29.5	−0.5	14.0	−0.0	13.5	+5.4	20.1	+9.3	23.5	−2.2	20.1	+2.2
Montana		33.2	+1.2	30.0	+7.6	25.4	+6.9	32.4	+11.2	35.0	+4.8	31.2	+6.3
Nebraska		38.0	+1.3	26.7	+0.9	26.6	+4.7	35.6	+10.5	36.4	+0.8	32.7	+3.6
New England		37.7	−0.4	26.1	−0.4	22.5	+0.3	20.4	−1.2	26.6	−4.0	26.7	−1.1
New York		37.6	+0.1	27.3	+1.1	24.3	+1.8	21.5	−0.4	27.0	−5.0	27.5	−0.5
North Dakota		28.8	+2.2	16.5	+3.5	16.3	+11.4	22.3	+14.4	25.8	+3.2	21.9	+6.9
Pennsylvania		39.5	−1.5	30.7	−0.2	27.8	0.0	28.7	+1.0	33.1	−4.4	32.0	−1.0
South Dakota		34.2	+0.6	22.1	+2.2	19.8	+4.0	29.0	+11.3	32.1	+1.2	27.4	+3.9

[1] Temperatures in italic type indicates warmest on record for Alaska.   [2] Second warmest on record.   [3] Fourth warmest on record.   [4] Third warmest on record.

It will be readily seen from this table that during January, 1926, Alaska averaged much warmer weather than the Dakotas, Minnesota, and nearly the same as the New England section, Michigan, and New York States. The minimum temperature for the winter at Juneau was only 24°, which is 13° higher than its previous highest winter minimum. This temperature is also 2° warmer than the winter minimum at New Orleans for the same year.

Beginning in the autumn of 1925, the dates of the closing along the Yukon River were in most cases about 10 days later than usual. The opening this spring at Eagle, which is the only station heard from so far, occurred on April 28, which is the earliest since records were started there in 1898. At Barrow, on the northern Arctic coast, the schooner *Baychima* left that place for the south on October 2. This is the latest date known for a vessel to leave those waters, the usual time being early September. Favorable winds were responsible. Easterly winds blow the Arctic ice pack away from the shore, while westerly winds blow the ice against the coast. Barrow also recorded an open sea until January 8, 1926, with only floating ice between October 22 and 31, inclusive. Such a condition is most unusual, as the Arctic ice pack generally returns to Barrow in the early fall.

In November the semipermanent Aleutian LOW pressure area was more intense than usual.[1] Barrow was the only station in Alaska where the air pressure averaged above the normal. As would be expected from a pressure distribution of this intensity, unseasonably warm and cloudy weather prevailed over all sections of the Territory, the only station with temperature below normal being at Barrow.

During December the Aleutian LOW was below the normal and not quite so intense as in November. It was, however, central considerably farther south and east, thus causing very mild and rainy weather over the panhandle of Alaska. With the exception of Juneau, southeastern Alaska experienced the warmest December on record.

The average barometric pressure for January was decidedly below the normal. As stated by the San Francisco district forcaster (2) in the MONTHLY WEATHER REVIEW for January, 1926, "It is very probable that the records of the past will not show barometric pressure so low and so persistently low as prevailed over the northeast Pacific Ocean throughout the month." This statement is fully verified by the pressure records from the Dutch Harbor station which have been received by mail. The average sea-level pressure for January at that place was 29.07 inches, as compared with the previous lowest January average of 29.43 inches in 1915. Beginning with latitude 52° N., the subdepartures of the mean monthly barometric pressure increased rapidly to the north and west, with the maximum subdeparture of 0.57 inch at Dutch Harbor and nearly half an inch over the Yukon Valley. These subdepartures are the greatest on record in Alaska. With an average low-pressure distribution of such intensity and magnitude and exerting its influence far into the interior of Alaska, it is not surprising that January, 1926, was by far the warmest on record for the greater portion of the Territory.

[1] In obtaining the average pressure of the Aleutian LOW area for each month, the daily pressure values at sea as far south as Honolulu and Midway Island were obtained from the San Francisco daily radiographic reports as published on the weather map. By interpolation the pressure values were computed for each 10 degrees of latitude and longitude as discussed by Reed (1) in the MONTHLY WEATHER REVIEW for January, 1926.

Sir Frederic Stupart (3), of the Canadian Meteorological Service, gives the following excellent explanation for the cause of some of the mild winters in Canada, and it is well worth quoting, as it also applies directly to Alaska:

In some years the North Pacific cyclonic areas appear to be of such intensity that they force their way into the continent in the high latitudes and *actually prevent* the formation of anticyclones and their concomitant low temperatures. These conditions lead to mild winters in Canada.

That is actually what occurred in Alaska throughout the past winter when anticyclones were in the process of formation. As an example of this, the only real or typical cold wave of the winter occurred over the interior on the morning of December 13, when an anticyclonic area was central over the upper Yukon Valley, accompanied by the coldest weather of the winter in the interior. Over the Gulf of Alaska a moderate low-pressure area prevailed. During the following 12 hours the LOW increased rapidly in intensity. At 8 p. m. the pressure was 29.14 inches at Cordova and was rapidly overpowering the interior HIGH. By the morning of the 14th the Gulf storm had further increased in intensity to 28.98 inches and the interior HIGH had entirely dissipated. Two other high areas formed later in the winter and each was quickly overpowered by the Aleutian LOW. The few cold waves which did enter the United States from the north undoubtedly moved in from the MacKenzie River district, or even farther eastward.

During February and March the Aleutian LOW remained centered over Dutch Harbor, with average readings of 29.25 and 29.27 inches, respectively. February was the only winter month when several interior stations reported temperatures below the normal, while, on the other hand, some coast stations in southeast Alaska experienced their warmest February on record. The two outstanding weather phenomena for March were the unprecedented high mean temperatures in most of the Territory and the lowest barometric pressure on record in Alaska, which occurred at Dutch Harbor on March 18, when a sea-level reading of 27.99 inches was recorded.

As the persistently low barometric pressure has been the direct cause for the very mild weather during the past winter, Tables 2 and 3 will be of interest and value to the meteorologist. Table 2 shows the average monthly pressures and departures for the Alaska stations during the winter of 1925–26, and Table 3 gives the pressure extremes and dates for each station since the stations were established.

TABLE 2.—*Average monthly sea-level pressures, with departures from normal (4), November, 1925, to March, 1926, inclusive*

Station	November		December		January		February		March		Seasonal average	
	1925	Departure	1925	Departure	1926	Departure	1926	Departure	1926	Departure	1925–26	Departure
Barrow	30.03	+0.63	30.09	+0.04	29.93	−0.11	36.02	−0.16	29.99	−0.13	30.01	−0.13
Bethel	29.49	−0.19	29.72	0.00	29.35	−0.46	29.55	−0.29	29.52	−0.38	29.53	−0.26
Cordova	29.42	−0.20	29.47	−0.19	29.46	−0.32	29.41	−0.41	29.72	−0.11	29.50	−0.25
Dutch Harbor	29.37	−0.22	29.50	+0.01	29.07	−0.57	29.25	−0.36	29.37	−0.46	29.31	−0.32
Eagle	29.71	−0.15	29.88	−0.08	29.70	−0.39	29.76	−0.28	29.82	−0.14	29.78	−0.21
Juneau	29.68	−0.08	29.69	−0.10	29.76	−0.13	29.59	−0.34	29.99	+0.05	29.74	−0.12
Kodiak	29.33	−0.21	29.45	−0.13	29.28	−0.36	29.33	−0.42	29.53	−0.22	29.38	−0.27
Nome	29.48	−0.24	29.73	−0.04	29.51	−0.38	29.72	−0.17	29.64	−0.22	29.58	−0.21
Noorvik	29.68	−0.15	29.90	+0.06								
St. Paul Island	29.40	−0.22	29.79	−0.18	29.29	−0.39	29.51	−0.15	29.41	−0.33	29.48	−0.25
Sitka	29.65	−0.05	29.64	−0.12	29.73	−0.16	29.53	−0.32	29.97	+0.09	29.70	−0.11
Tanana	29.68	−0.14	29.88	−0.06	29.62	−0.45	29.75	−0.31	29.77	−0.27	29.74	−0.25
Honolulu	30.03	−0.00	29.94	−0.07	30.02	+0.02	30.06	+0.01		+0.03	30.02	0.00
Midway Island [1]	30.11	+0.04	29.84	−0.20	29.97	−0.03	29.99	−0.04	30.07	−0.01	30.00	−0.05

[1] One observation only (6.30 p. m. local time).
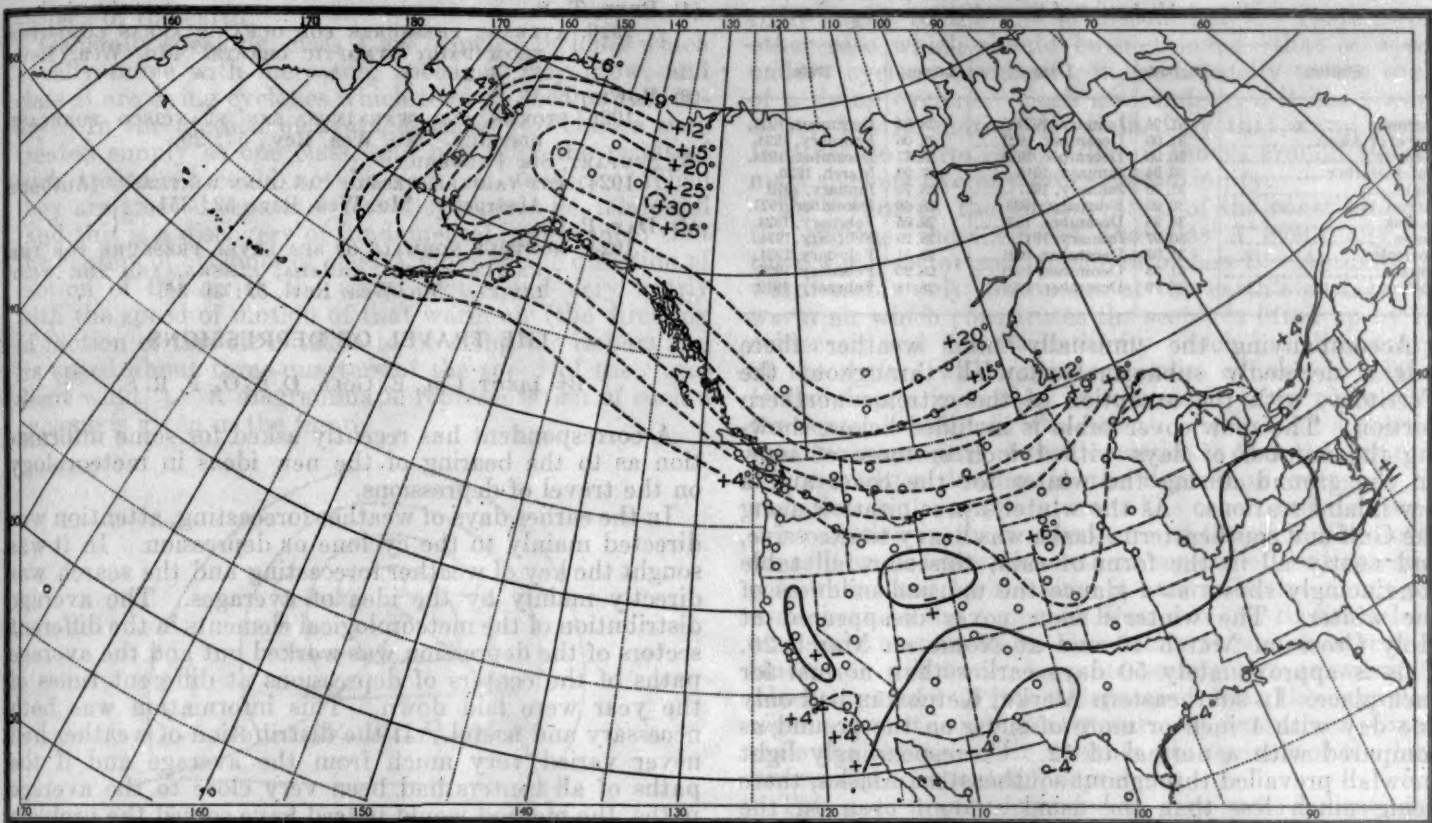
FIG. 1. Temperature departures for Alaska, Canada, and the United States for January, 1926
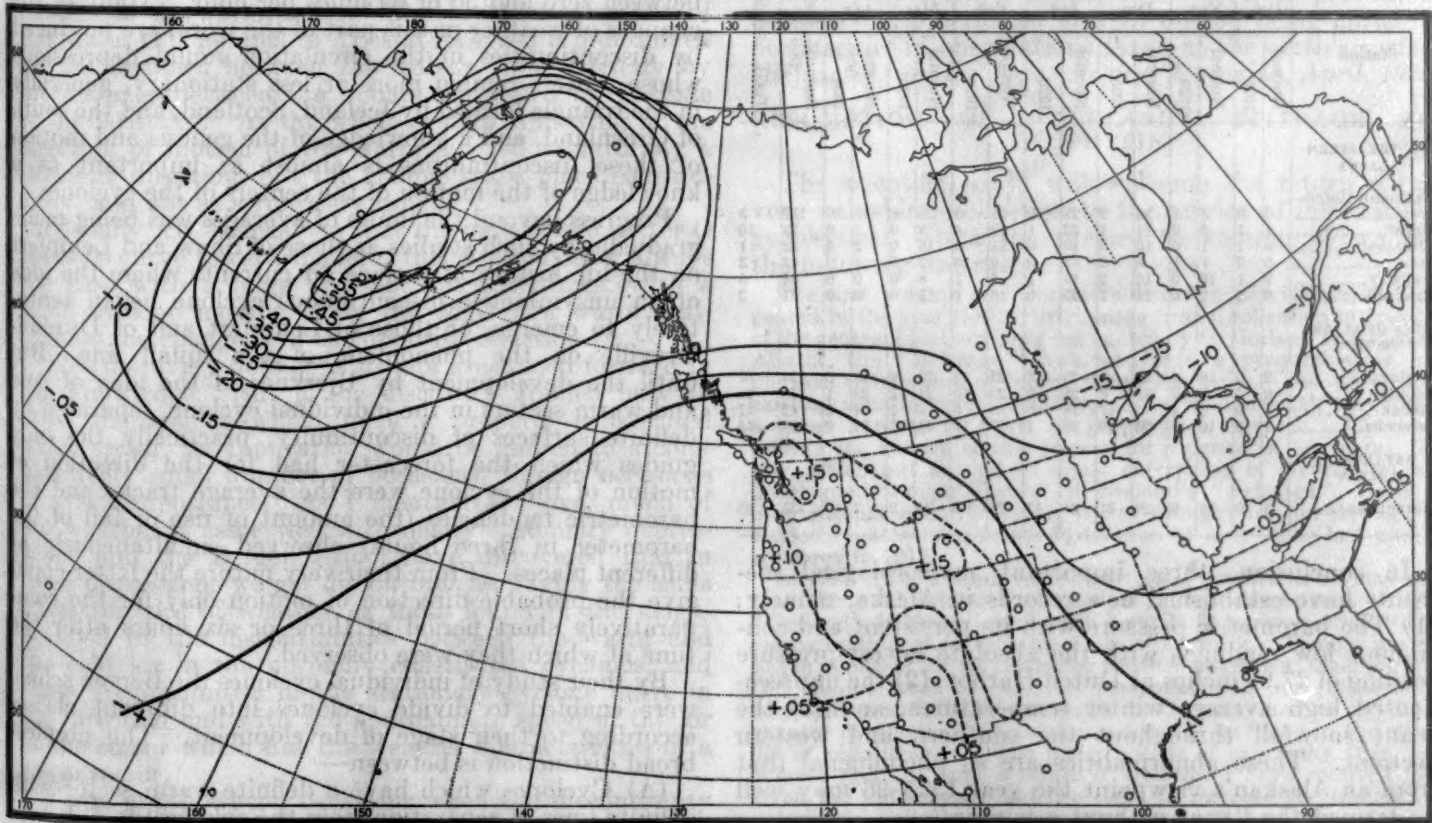
FIG. 2. Average sea-level pressure departures over the eastern Pacific Ocean for January, 1926

TABLE 3.—*Highest and lowest sea-level pressures, with dates, since the establishment of the stations*

Station	Highest	Date	Lowest	Date
Barrow	31.24	January, 1924	28.84	December, 1921.
Bethel or Akiak	31.00	December, 1921	28.06	February, 1924.
Cordova	30.96	December, 1924	28.37	December, 1924.
Dutch Harbor	30.94	January, 1916	27.99	March, 1926.
Eagle	31.30	January, 1917	28.74	January, 1910.
Juneau	30.93	February, 1923	28.06	December, 1921.
Kodiak	30.98	December, 1921	28.05	February, 1924.
Nome	30.97	January, 1917	28.29	February, 1924.
Noorvik	31.05	December, 1921	28.51	February, 1924.
Tanana	31.23	December, 1921	28.20	February, 1923.
Valdez	30.99	December, 1921	28.18	February, 1910.

Accompanying the unusually mild weather there was a decidedly subnormal snowfall throughout the Territory, with the exception of the extreme northern portion. The snow cover table is included below, showing the number of days with 1 inch or more of snow on the ground during the winter for the coast and a few inland stations. As the winter's precipitation along the Gulf and southeastern Alaska was heavy to excessive, and nearly all in the form of rain, this snowfall table convincingly shows at a glance the unusual mildness of the winter. The winter's snow cover disappeared at Holy Cross on March 10 and at Nome on March 29. This is approximately 50 days earlier than normal for each place. In southeastern Alaska, Ketchikan had only one day with 1 inch or more of snow on the ground as compared with a normal of 52. Correspondingly light snowfall prevailed throughout southeastern Alaska, there being much less than the usual amount even on the elevated regions.

TABLE 4.—*Normal and actual number of days with 1 inch or more of snow on the ground October 1, 1925, to April 30, 1926*

Station	Oct. Normal	Oct. 1925	Nov. Normal	Nov. 1925	Dec. Normal	Dec. 1925	Jan. Normal	Jan. 1926	Feb. Normal	Feb. 1926	Mar. Normal	Mar. 1926	Apr. Normal	Apr. 1926	Seasonal normal	Total, 1925–26
SOUTHEASTERN ALASKA																
Fortmann Hatchery	0	0	3	1	22	2	27	0	24	0	25	0	16	0	117	3
Juneau	1	1	5	0	14	4	22	1	19	4	8	0	3	0	72	10
Ketchikan	0	1	1	0	10	0	10	0	13	0	16	0	2	0	52	1
Sitka	0	0	1	1	8	2	11	0	9	0	12	0	1	0	42	3
Skagway	2	1	10	0	16	2	13	1	5	1	8	0	0	0	54	5
Wrangell	0	0	2	0	14	1	22	0	16	1	13	0	0	0	67	2
GULF OF ALASKA SECTION																
Cordova	2	0	10	6	22	29	28	5	23	17	23	4	16	0	124	61
Katalla	0	0	3	2	15	8	28	0	26	16	21	2	25	1	118	29
Kodiak	1	0	3	4	9	7	18	0	18	5	9	1	4	0	62	17
Latouche	1	0	10	1	26	29	30	1	27	17	31	7	20	0	154	55
MATANUSKA VALLEY																
Matanuska	3	0	16	9	29	31	31	17	28	8	21	2	7	0	135	65

In conclusion, three important meteorological elements have established new records in Alaska, namely: (1) The barometric pressure with its persistent and continuous low readings, with the absolute lowest pressure reading of 27.99 inches at Dutch Harbor; (2) the unprecedented high average winter temperatures; and (3) the scant snowfall throughout the southern and western sections. These abnormalities are so phenomenal that from an Alaskan's viewpoint the year 1925–26 may well be termed the "year without a winter."

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THE TRAVEL OF DEPRESSIONS

By LIEUT. COL. E. GOLD, D. S. O., F. R. S.

A correspondent has recently asked for some information as to the bearing of the new ideas in meteorology on the travel of depressions.

In the earlier days of weather forecasting, attention was directed mainly to the cyclone or depression. In it was sought the key of weather forecasting and the search was directly mainly by the idea of averages. The average distribution of the meteorological elements in the different sectors of the depression was worked out and the average paths of the centers of depressions at different times of the year were laid down. This information was both necessary and useful. If the distribution of weather had never varied very much from the average and if the paths of all centers had been very close to the average paths, the method would indeed have solved the problem of forecasting; but actually the distribution of weather in a cyclone varies between wide limits and the centers of cyclones move on tracks which are separated widely apart and the speed of the centers along the tracks vary between zero and 50 or 60 miles per hour. Many of the changes of weather in this part of the world are produced by discontinuities in the circulation round depressions whose centers remain more or less stationary, generally in the triangle formed by Iceland, Scotland, and the south of Greenland, and a knowledge of the genesis and motion of these discontinuities is almost as important as a knowledge of the motion of the centers of the cyclones.

Progress beyond the limits of averages was being made gradually by such studies as those of Shaw and Lempfert on the life history of surface air currents where the idea of an unsymmetric discontinuous cyclone began tentatively to emerge, or those of Lempfert and of Durand-Gréville on the phenomena of the squall line. But until the development by Bjerknes of the idea of cold and warm sectors in the individual cyclone, separated by definite surfaces of discontinuity, practically the only guides which the forecaster had for the direction of motion of the cyclone were the average tracks and the barometric tendencies (the amount of rise or fall of the barometer in three hours) observed simultaneously at different places. From their very nature the latter could give the probable direction of motion only for the comparatively short period of three or six hours after the time at which they were observed.

By their study of individual cyclones the Bergen school were enabled to divide cyclones into different classes according to their stage of development. The simplest broad distinction is between—

(A) Cyclones which have a definite warm sector with definite lines of separation from the cold sector.

(B) Cyclones in which there is no warm sector at the surface of the earth.

Generally speaking, class A are growing cyclones which usually move with increasing speed as they grow, and class B are dying cyclones which tend to become stationary. In the method of averages these two classes were treated simply as one class, and naturally the result of such treatment could not be very satisfactory. When they are treated separately, as they should be, it is found (and this is a discovery of fundamental importance) that the centers of cyclones of class A move in the direction of motion of the air in the warm sector and very nearly with the speed of motion of that warm air (the direction of motion of this air is taken to be along the isobars and its speed about three-quarters of the speed of the "gradient wind"). A diagrammatic representation of such a cyclone is given in the figure.
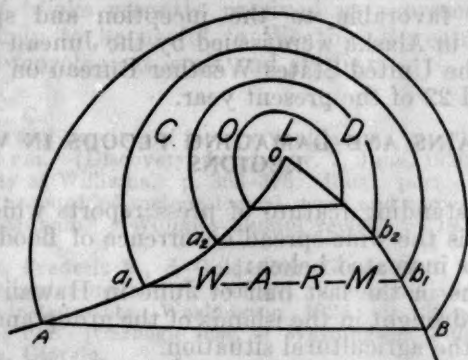
OAB is the warm sector; OA and OB are the lines of discontinuity dividing the warm air from the cold air. The lines $a_1 b_1$, $a_2 b_2$, etc., are isobars; they are drawn straight because in practice they are found to be nearly straight in the warm sector. The direction of motion of the center O is parallel to AB and its speed is determined by the distance between the isobars (more strictly by the distance between the isobars multiplied by the sine of the latitude). As the whole system is moving in the direction of motion of the warm air, AB is naturally a changing direction, but the change takes place continuously, and not as a rule very rapidly.

(Usually AB "backs" so that the path of the center O tends to curve toward the left; this is practically always the case with a large cyclone; but sometimes, with a small cyclone moving along the edge of a warm anticyclone the change is in the opposite direction.)

This discovery does constitute a great step forward in our knowledge. But if the discovery applied only to those depressions which have a properly constituted warm sector, its application would be limited to a comparatively small number of occasions, though occasions of great importance. As I mentioned above, much of our weather is associated with nearly stationary depressions, and the Bergen school have discovered that in these depressions we get discontinuities having the same characteristics of weather as those found in the neighborhood of the discontinuities between the warm and the cold air in the normally constituted cyclones; and these discontinuities in the stationary cyclone move in the direction and with the approximate speed of the air in the sector which has the weather characteristics of a warm sector.

There are, however, occasions when the discontinuity in the stationary cyclone is practically a single discontinuity and no distinctive warm sector can be identified; in such cases the discontinuity moves around the cyclone at a speed equal to the component of the colder wind at right angles to the line of discontinuity. There is one other case which should be mentioned—that of a secondary cyclone developing in, and usually to the south of a dying cyclone. Such a secondary, if it has a warm sector, has its motion determined by that warm sector. If it has no warm sector, then it moves around the primary cyclone like any other discontinuity.

To return to the consideration of the constitution of the cyclone, those classed above as A eventually lose their warm sector and change into class B. Actually the warm sector only disappears at the earth's surface; the warm air which constitutes the sector is lifted up by the colder air and the discontinuity which has disappeared at the surface will continue to exist at greater heights. If the change from class A to class B takes place while the center is still over the Atlantic (or in such a position that the major part of the depression is over the Atlantic) discontinuities develop in the depression owing to the variation in the temperature of the ocean and the resulting variation in the temperature of the air. The (cold) air as it approaches the southern regions of the depression gets warm, and by the time it has made the circuit and come back to the region of France or the British Isles it may have become warm air relative to the air over these lands. It will never be quite so effective as warm air which has come up into a depression from the equatorial regions, but it is sufficiently warm to produce on a small scale the characteristic weather phenomena of the large "normally constituted" depression.

This note is only intended to give some indication of the way in which the question put by our correspondent is being answered. It is not possible to give in simple language in a short article anything like a complete account of the results of the long technical investigations of other people, nor to explain in detail all the precautions necessary in practice to prevent oneself being misled by peculiarities in observations taken at the earth's surface. (*Reprinted from the Meteorological Magazine, April, 1926.*)

RESUMPTION OF "GERLAND'S BEITRÄGE ZUR GEOPHYSIK"

The scientific world will welcome the return of this very valuable publication to the service of international geophysics. From the preface to volume 15 we take the following excerpts:

The first volume of "Gerland's Beiträge zur Geophysik" appeared in the year 1887. Originating from a collection of treatises of the geographical seminary conducted by G. Gerland of Strasburg, Alsatia, the "Beiträge" developed into a predominating geophysical publication of international character. The 14 volumes existing contain many treatises, partly fundamental, taken from a great number of fields of geophysical research. The series reflects the history of this science for a period of 30 years. The war, which put an end to many enterprises of civilization, also interrupted the publication of Gerland's "Beiträge." Being an international scientific organ, it was brought to ruin through the tendencies attaching to the institution of war. The last number appeared in 1918.

In view of the gradual return to normal conditions we may hope that the good intention of the publisher, who intends to issue "Gerland's Beiträge" again, will contribute to some extent to the reconstruction of international scientific work. Thanks are due to the publisher for his interprise which is to serve an ideal purpose. But thanks must be returned particularly to our colleagues in neighboring and distant countries, in Germany and in my native country of whom only a small number will be found in the official list of collaborators. The many tokens of sympathy they have evinced and the large number of treatises I have received have given me the courage and the right to recreate the tradition of "Gerlands' Beiträge zur Geophysik." * * *

True to the tradition of the "Beiträge," these pages will be placed at the disposal of scientists in every country of the world. In consideration of the fact that contributions may be submitted

in German, English, and French, thus facilitating difficulties of expression, all colleagues should be in a position to cooperate. There is no limit to the length of the contributions to "Gerland's Beiträge zur Geophysik," and the use of foreign languages will be an appreciated attribute. * * *

In general, the more detailed abstracts and reviews will replace the usually short ones. A list of the literature treating with geophysical research during the years 1914–1923 will be issued later on. On both sides the war interrupted the regular exchange of publications. The interruption thus caused—the gap brought about by the war—will be repaired as far as humanly possible.

The collaborators will be presented with 50 reprints of their treatises.

The publication will appear in single numbers, but will be calculated by volumes. Every effort will be made to publish the treatises as quickly as possible. Treatises should be submitted to the editor, who also replies to all questions.

The editor: Prof. Dr. V. Conrad, Mariahilferstr. 91, Vienna.

The publisher: Akademische Verlagsgesellschaft m. b. H., Leipzig.

TORNADO CLOUDS AT TOPEKA, KANSAS, JUNE 16, 1926

By S. D. FLORA, Meteorologist

Two small tornado clouds appeared at the eastern edge of Topeka at about 5 p. m. of June 16, moved east in almost parallel paths, and dissipated without serious damage.

One of these apparently originated at the eastern edge of North Topeka, just north of the Santa Fe shops. A man who saw the formation of the cloud stated it was caused "by two clouds coming together"—a very common observation of the origin of a tornado cloud.

The only member of the office force who witnessed the cloud was E. C. Corkill, junior observer, who first noted it from the office window at Fifth and Kansas Avenues, about 2 miles distant in an air line. Mr. Corkill first noticed it at 5.08 p. m., apparently a minute or two after it formed. His report states the upper part of the cloud was funnel shaped, extending down from an exceptionally threatening thunderstorm cloud. The lower part of this funnel terminated in a long light grey cloud, resembling an enormous rope dangling from it. A small boy who saw this cloud reported it was a "snake in the sky." This rope-shaped cloud seemed to drag from the parent funnel, twisting itself almost at right angles at times and darting towards the ground but, apparently, never quite reaching it, as seen from the office window. Subsequent events showed, however, that it extended to the ground once just east of the county line, about 4 miles from its point of origin. At this place, between the Union Pacific tracks and the Kansas River, near the old Jesse Willard farm, occurred the only damage that was reported. Several small farm buildings sustained minor damage, some trees were blown down, and a farm hand was picked up and carried about 60 feet and let down with no injury except a bad fright and a coating of mud.

The cloud disappeared about a mile east of this point by gradually drawing up into the thundercloud above, maintaining its funnel shape to the last. Mr. Corkill noted its disappearance at 5.17 p. m., which gave its rate of progression as about 5 miles in nine minutes.

The other cloud was first noted at about 5 p. m. just east of the city ball park, about 3 miles north of the cloud first described. It was practically of the same type and was in sight for about the same length of time. So far as could be ascertained it failed to reach the ground and did no damage whatever.

A display of mammato-cumulus clouds, covering about a tenth of the sky, preceded the tornado clouds a few minutes.

Another tornado cloud of about the same type was observed at about the same time 14 miles southwest of Topeka, 2 miles east of Auburn, moving east. It failed to reach the ground and did no damage.

THE WINTER 1924–25 IN ITALY

L. Borriello in *La Meteorologia Practica* for March–April, 1926, discusses the winter of 1924–25 in Italy, using the records of eleven stations well distributed over that country. Each of the winter months, December, January and February were warm, the average deviation from the normal being +1.5, +1.2 and +1.5° C., respectively. The cause of the warm winter is ascribed to the pressure distribution over central and southern Europe.—*A. J. H.*

FIRST WARNINGS OF FOREST-FIRE WEATHER IN ALASKA

The editor is informed that the first warnings of weather conditions favorable to the inception and spread of forest fires in Alaska were issued by the Juneau (Alaska) Office of the United States Weather Bureau on June 18, 19, 21, and 22 of the present year.

HEAVY RAINS AND DAMAGING FLOODS IN VARIOUS REGIONS

The outstanding feature of press reports which reach the editor is the wide-spread occurrence of flood-producing rains as indicated below:

(1) Rains in the last half of June in Hawaii broke a 5-months' drought in the islands of the group and greatly improved the agricultural situation.

(2) Heavy rains and floods occurred in central and western Europe in May and continued in parts of the Balkans and elsewhere in June, 1926, with some loss of life and great damage to crops.

(3) Six thousand families homeless and a loss of life, estimated at 1,000 persons, are reported incident to the bursting of a dam as the result of torrential rains in the vicinity of Leon, Guanajuato, a city of 65,000 inhabitants, situated in the midst of a highly cultivated agricultural district of Mexico about 1,000 miles south of the Rio Grande. Subsequent reports from Mexico show a continuation of heavy rains during July with much flooding in the great central valley in which Mexico City is situated.—*A. J. H.*

METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA

By Senior J. B. NAVARRETE

[El Salto Observatory, Santiago, Chile]

During May occurred important meteorological changes which brought the beginning of the normal rainy season in the central zone. The paths of the low centers inclined progressively toward the north.

Between the 3d and 7th low pressure dominated the far south, falling to a minimum of 737 mm. on the 5th at Punta Arenas. Bad weather with frequent rains covered the whole southern zone as far north as Concepcion Province. The maximum precipitation for 24 hours was recorded on the 4th at Cabo Raper, 32 mm.

Between the 6th and 14th, pressure rose in the south, setting up anticyclonic control, with general fine weather, cold and frosts.

Between the 15th and 18th a new depression crossed southern South America, causing bad weather and rains as far north as Concepcion. Maximum precipitation for 24 hours was recorded on the 17th at Valdivia, 29 mm.

On the 19th a large depression appeared from the west, in the latitude of Isla Mocha. On the 20th, foul weather set in over the south, with heavy winds and rains. On the island of Huafo the mean wind velocity reached 1,700 m. p. m. (63 m. p. h.). On the 21st the rains extended into the Central Zone, reaching northward as far as Coquimbo Province. Rainfall of 47 mm. was registered at Valdivia, 26 mm. at Talca, and 15 mm. at Coquimbo. Between the 22d and 24th the depression weakened as the result of convergence of strong winds, in harmony with the laws of Guilbert.

From the 25th to the 31st the weather remained unstable, with frequent alternations of high and low pressure in the south. The most important depression of the period occurred during the 29th to 31st. It rained from Aconcagua Province to Valdivia, precipitation in the south ranging from 30 to 40 mm.

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RECENT PAPERS BEARING ON METEOROLOGY

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meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING JUNE, 1926

By Herbert H. Kimball, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the Review for January, 1924, **52**: 42, January, 1925, **53**: 29, and July, 1925, **53**: 318.

From Table 1, it is seen that solar radiation intensities averaged above the normal for June at all three stations.

Table 2 shows a decided excess in the amount of radiation received on a horizontal surface from the sun and sky at Madison, a slight excess at Lincoln, and a pronounced deficiency at Washington.

Skylight polarization measurements made on four days at Washington give a mean of 54 per cent, with a maximum of 56 per cent on the 28th. Measurements made on six days at Madison give a mean of 60 per cent, with a maximum of 64 per cent on the 8th. These are close to the corresponding averages for June for the respective stations.

Table 1.—*Solar radiation intensities during June, 1926*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	8a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
					Air mass						Local mean solar time
	75th mer. time		A. M.					P. M.			
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
June 2	10.97			0.41	0.71						7.87
8	10.59					1.14					11.81
9	8.81		0.59	0.81	1.03	1.32					8.18
10	9.83					1.24					8.48
11	7.29				1.16						8.48
17	8.48			0.92							8.18
21	9.14		0.77	0.90	1.05	1.20					9.47
25	11.81			0.72	0.90	1.17					12.24
28	9.14		0.80	0.96	1.16	1.45	1.01				7.04
29	12.24					1.22					11.38
30	13.61			0.84	0.94	1.05					12.68
Means			0.72	0.79	0.99	1.22	(1.01)				
Departures			+0.10	+0.07	+0.10	+0.01	+0.09				

* Extrapolated.

Table 1.—*Solar radiation intensities during June, 1926*—Contd.

MADISON, WIS.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
					Sun's zenith distance						
					Air mass						
	75th mer. time		A.M.					P. M.			solar time
	e.	5.0	4.0	3.0	2.0	¹1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
June 1	7.57					1.33					8.81
3	6.76				1.09	1.38					8.18
4	6.76					1.35					6.50
5	7.04		0.88	1.00							6.76
8	8.18		0.93	1.05	1.19						8.18
9	9.47				1.21	1.37					8.81
15	7.29				1.14	1.37					8.18
19	6.27					1.37					7.29
23	9.14				1.21	1.44					9.14
26	7.57		0.86	0.97	1.15						9.47
30	9.14					1.39					7.29
Means			0.89	1.01	1.16	1.38					
Departures			+0.01	+0.04	+0.06	+0.06					

LINCOLN, NEB.

Date											
June 1	6.27		0.71	0.98	1.23	1.43					4.95
2	7.29		0.80	0.95	1.12	1.37					7.29
4	9.83					1.43	1.18	1.00	0.89		8.81
6	8.48						1.08	0.81			5.56
7	8.18						1.11	0.93	0.79		6.02
16	14.10					1.13					16.79
17	9.14			1.07	1.26	1.48	1.13	0.97			7.87
23	9.14		0.78	0.94	1.19	1.36					7.57
26	7.04			0.93	1.19	1.28	1.10	0.92			6.50
27	8.48		0.95	1.02	1.27						8.48
Means			0.81	0.98	1.21	1.39	1.12	0.93	0.84		
Departures			+0.04	+0.05	+0.11	+0.04	+0.03	+0.03	+0.07		

Table 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation					Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Washington	Madison	Lincoln
1926	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 4	393	638	630	463	358	−101	+141	+90
11	427	412	480	314	369	−67	−98	−73
18	425	585	530	508	377	−69	+62	−43
25	575	538	639	468	460	+84	+4	+52
Excess since first of year on July 1						+1,694	+3,521	+756

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The quiet weather that prevailed during May continued throughout the greater part of June, when the number of days with winds of gale force not only showed a considerable decrease over the previous month, but was also below the normal for June. In each of the two 5° squares between 40° and 50° N. and 35° and 40° W. gales were reported on 3 days, while in no other square were they observed on more than 2 days. While a number of well defined depressions developed during the month, they were as a rule of slight intensity and devoid of any marked characteristics, and of not enough importance to warrant the preparation of the usual charts.

Fog was again unusually prevalent; along the American coast and over the Grand Banks it was reported on from 10 to 20 days, while it was also more frequent than usual over the steamer lanes, especially between the 45th and 55th parallels and 10th and 20th meridians.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressures at sea level, 8 a. m. (75th meridian), North Atlantic Ocean, June, 1926*

Stations	Average pressure	Depart-ure [1]	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	[3] 29.71	([3])	29.97	28th	29.30	1st.
St. Johns, Newfoundland	29.85	−0.12	30.20	18th	29.20	13th.
Nantucket	29.92	−0.07	30.28	17th [4]	29.52	7th.
Hatteras	29.96	−0.05	30.12	17th	29.65	7th.
Key West	29.99	−0.01	30.08	1st [4]	29.88	7th.
Swan Island	29.87	0.00	29.94	14th	29.82	6th. [4]
New Orleans	29.97	+0.02	30.08	10th [4]	29.86	5th.
Turks Island	30.05	+0.04	30.16	7th	30.00	19th. [4]
Bermuda	30.18	+0.08	30.32	26th	29.94	14th.
Horta, Azores	30.14	−0.09	30.46	6th [4]	29.72	25th.
Lerwick, Shetland Islands	29.89	+0.09	30.33	28th	29.52	11th.
Valencia, Ireland	29.95	−0.05	30.45	26th	29.25	11th.
London	29.93	0.00	30.38	28th	29.45	12th.

[1] From Normals shown on H. O. Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m., 75th meridian.
[2] Mean of 24 observations; 6 days missing.
[3] New station; no normal established.
[4] And on other dates.

On the 1st there was a fairly well-developed depression central near 40° N., 55° W., with northeasterly gales in the northwesterly quadrant. On the same day Stornoway, Scotland, was near the center of a second LOW, and light to moderate winds only were reported by land stations on the British Isles and also by vessels along the European coast, although moderate westerly gales prevailed over a limited region east of the Azores.

On the 3d Father Point, Quebec, was near the center of a depression that moved slowly eastward, and on the 5th was in the vicinity of Belle Isle. Moderate weather was the rule over the entire ocean during this period, except that on the 3d northwesterly gales occurred over the eastern section of the steamer lanes.

On the 6th a slight disturbance was near Hatteras that drifted slowly northeastward along the coast, and on the 9th was over the Province of Quebec, while moderate gales were reported by vessels between Charleston and Nantucket, although quiet weather prevailed over the greater part of the ocean.

From the 8th to the 11th westerly to northwesterly gales occurred over a portion of the eastern section of the steamer lanes. On the 11th the disturbance causing these gales was central near Malin Head, Ireland, where the lowest barometric reading of the month, 28.91 inches, was recorded.

On the 12th and 13th Newfoundland was covered by a slight depression and moderate westerly to southwesterly gales were encountered between the 40th and 45th parallels and the 40th and 55th meridians.

On the 15th a LOW was near 45° N., 45° W., that moved rapidly eastward, increasing in intensity; being on the 16th central near 52° N., 32° W., and on the 17th near 54° N., 20° W. A few vessels reported westerly gales over the eastern half of the steamer lanes, although for the most part, favorable weather prevailed.

A LOW that on the 16th was near 40° N., 60° W., moved steadily eastward and on the 17th was in the vicinity of 40° N., 45° W. On both of these dates, as well as on the 18th, westerly gales prevailed over a limited area along the 40th parallel, between the 55th meridian and American coast.

On the 19th and 20th another disturbance appeared over Newfoundland and on the latter date a southerly gale was encountered by a vessel near 40° N., 57° W., although other ships in the vicinity reported only moderate winds.

On the 22d a shallow depression was central near 45° N., 40° W., that moved but little during the next 24 hours but increased considerably in intensity. During the period from the 22d to 24th gales occurred between the 40th and 45th parallels and the 30th and 45th meridians.

From the 25th until the end of the month moderate weather prevailed over the entire ocean, with high pressure generally over the middle and eastern sections.

OCEAN GALES AND STORMS JUNE, 1926

Vessel	Voyage From—	Voyage To—	Latitude	Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN								*Inches*					
McKeesport, Am. S. S.	New York	Havre	40 25 N.	56 30 W.	1st	2 a., 1st	1st	29.90	NE	NE., 8	NE	NE., 8	Steady.
Tetonia, Ger. S. S.	Hamburg	Guatemala	42 20 N.	20 00 W.	1st	—, 1st	1st	29.97	SW	SW., 8	WSW	—, 8	
Wellfield, Br. M. S.	English Channel.	Key West	42 00 N.	38 46 W.	2d	3 p., 2d	3d	29.35	SSE	—	NW	NW., 9	SW.-W.-NW.
M. F. Elliott, Am. S. S.	New York	Texas City	32 25 N.	76 10 W.	6th	5 a., 6th	6th	29.67	SSW	SSW., —	SSW	SW., 11	Steady.
Burgondier, Belg. S. S.	Port Said	Hampton Roads.	36 55 N.	69 55 W.	8th	4 p., 9th	9th	30.01	S	SSW., 8	W	SSW., 8	SSW.-NW.
Stockholm, Swed. S. S.	Gothenburg	New York	49 24 N.	35 24 W.	9th	8 a., 10th	10th	29.45	WNW	WNW., 3	WNW	—, 8	NW.-SE.-SW.
Baxtergate, Br. S. S.	Rotterdam	Hampton Roads.	42 56 N.	45 04 W.	11th	Noon, 12th	12th	29.67	S	SW., 9	SW	SW., 9	S.-SW.
Denham, Br. S. S.	...do	...do	50 04 N.	12 27 W.	9th	4 a., 12th	13th	29.22	WSW	SW., 8	WNW	WNW., 9	SW.-W.
West Hika, Am. S. S.	Hamburg	Pensacola	47 50 N.	10 26 W.	13th	8 p., 13th	14th	29.46	W	W., 7	WNW	WNW., 8	Steady.
Baxtergate, Br. S. S.	Rotterdam	Hampton Roads.	42 15 N.	61 57 W.	15th	Mdt. 15th	16th	29.54	NE	NE., 8	NE	NE., 8	Do.
United States, Dan. S. S.	Oslo	New York	48 40 N.	36 30 W.	16th	5 p., 17th	18th	29.14	SE	S., 7	NW	NW., 9	SE.-S.-SW.-NW.
Bird City, Am. S. S.	Copenhagen	Boston	56 07 N.	23 20 W.	18th	4 a., 19th	19th	29.57	SW	SW., 8	SW	—, 8	Steady.
Innoko, Am. S. S.	New York	Rotterdam	41 15 N.	54 32 W.	19th	4 a., 20th	20th	29.76	S	SSE., 7	NNW	—, 8	SSE.-NNW.
Gaasterdijk, Du. S. S.	Rotterdam	Galveston	44 10 N.	38 26 W.	22d	10 p., 22d	23d	29.60	ENE	N., 9	NNW	NNW., 9	ENE.-N.
Pres. Polk, Am. S. S.	Marseille	Boston	41 25 N.	34 20 W.	23d	6 a., 23d	24th	29.51	WNW	SW., 7	N	WNW., 10	WNW.-N.
Waaldijk, Du. S. S.	Las Palmas	Rotterdam	43 42 N.	9 13 W.	28th	4 p., 28th	29th	29.96	ENE	E., 7	ENE	E., 8	N.-NE.-E.
NORTH PACIFIC OCEAN													
India Arrow, Am. S. S.	Shanghai	San Francisco.	44 13 N.	155 33 W.	May 31	3 a., 1st	1st	29.72	SW	SSW., 9	SW	SSW., 9	SW.-SSW.-SW.
Robert Dollar, Br. S. S.	Karatsu	San Pedro	43 17 N.	137 30 W.	...do	3 a., 2d	3d	29.61	SSW	SSW., 8	SSW	SSW., 8	Steady.
Tamaha, Br. S. S.	Hongkong	San Francisco.	44 24 N.	139 57 W.	June 1	Noon, 2d	3d	29.68	SSW	S., 9	SSW	S., 9	S.-SSW.
Maunaweli, Am. S. S.	Port Allen	...do	37 30 N.	124 W.	June 4	4 a., 5th	5th	29.78	N	NNW., 7	NNW	NNW., 8	Steady.
Canad. Importer, Br. S. S.	San Pedro	Vancouver	42 27 N.	125 W.	June 8	2 p., 8th	9th		N	N., 7	N	N., 9	Do.
China Arrow, Am. S. S.	San Francisco.	Hongkong	40	150 20 E.	June 7	Noon	7th	29.93	SE	SE., 8	SW	SE., 8	SE.-SW.
Do	...do	...do	28 24 N.	128 E.	June 12	1 a., 13th	13th	29.47	E	NE., 10	NE	NE., 10	ESE.-NE.
Pres. Lincoln, Am. S. S.	Shanghai	Honolulu	34 19 N.	138 E.	June 13	9 a., 14th	14th	29.18	ENE	NE., 10	NE	NE., 11	ENE.-NE.
West Chopaka, Am. S. S.	San Francisco.	Yokohama	35 40 N.	142 30 E.	June 13	1 a., 15th	15th	29.20	ENE	N., 11	N	N., 11	Steady.
Shintoku Maru, Jap. S. S.	Muroran	San Diego	39 45 N.	144 09 E.	June 14	9 a., 15th	15th	29.05		SW., —		E., 8	SE.-WSW.
Duchessa d'Aosta, It. S. S.	San Francisco.	Balboa	15 20 N.	96 25 W.	June 13	9 p., 13th	14th	29.55	ESE	NE., 9	NNE	NE., 10	NE.-NNE.
Sonoma, Am. S. S.	Sydney, N. S. W.	San Francisco.	36 40 N.	125 40 W.	June 14		14th	29.91	NNW	NW., 8		NW., 8	Steady.
Oakridge, Am. S. S.	Dairen	...do	47 40 N.	161 10 W.	June 17	8 p., 17th	18th	29.70	E	ENE., 7	E	ENE., 8	Do.
Bessemer City, Am. S. S.	Los Angeles	Kobe	36 02 N.	162 42 E.	June 26	8 a., 27th	27th	29.58	S	SSW., 8	WSW	SSW., 8	SSW.-SW.
SOUTH PACIFIC OCEAN													
Tahiti, Br. S. S.	San Francisco.	Sydney, N. S. W.	34 18 S.	152 20 E.	June 11	2 a., 12th	12th	29.87	NW	SW., —	SW	WNW., 8	WNW.-SW.
SOUTH ATLANTIC OCEAN													
Alchiba, Du. S. S.	Bahia Blanca	Antwerp	36 43 S.	55 22 W.	...do	Noon, 11th	12th	29.29	WSW	WSW., 7	SW	WSW., 9	WSW.-W
Crofton Hall, Am. S. S.	Norfolk	Montevideo	34 30 S	53 40 W.	...do	5 a., 11th	12th	29.29	WSW	W., 6	SW	WSW., 9	W.-WSW

NORTH PACIFIC OCEAN

By WILLIS EDWIN HURD

The weather would have been exceptionally fine on the North Pacific Ocean during June had it not been for the frequent and widespread fog over a large part of the northern half. More steamers than usual reported it and some experienced it continuously for several days in succession. There was no day without its occurrence over some considerable area or areas north of the 35th parallel. Fog lessened rapidly to the southward, and below the 30th parallel it was not reported except on the 14th, near Cape San Lucas.

There was considerable movement of HIGHS and LOWS especially in middle latitudes, but the resulting winds did not attain full storm force, so far as known, except in a typhoon off the Japanese coast, and the gales that did arise appeared only over scattered local areas.

The average atmospheric pressure was close to the normal, the only considerable departure, so far as known, occurring north of the 55th parallel. At the Pribilof Islands pressure was 0.20 inch above the normal, due to the considerable northward movement of high pressure areas. The Aleutian LOW existed only as a huge, shallow, and irregular area over the Gulf of Alaska and adjacent waters to the westward. Its average pressure was only slightly less than 30 inches, although its central pressure, upon one occasion early in the month, dropped nearly to 29 inches.

The North Pacific HIGH was never entirely displaced. It overlay the coast at Washington and British Columbia, and thence extended southwestward, with the center averaging near 40° to 45° N., 140° to 145° W. The reports of some vessels showed an absence of trade winds between California and the Hawaiian Islands, while others indicated them to be weaker and unsteadier than usual.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean, June, 1926*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Dutch Harbor [1]	29.96	−0.03	30.36	7th	29.54	3d.
St. Paul [1]	30.09	+0.20	30.50	8th	29.58	5th.
Kodiak [1]	29.98	+0.04	30.46	7th	29.08	3d.
Midway Island [1][4]	30.02	−0.05	30.22	4th [3]	29.68	16th.
Honolulu [4]	29.99	−0.05	30.10	2d	29.78	8th.
Juneau [4]	29.99	−0.02	30.27	6th	29.40	26th.
Tatoosh Island [4][5]	30.09	+0.04	30.34	5th	29.79	24th.
San Francisco [4][5]	29.92	−0.04	30.06	4th	29.77	5th.
San Diego [4][5]	29.91	+0.02	30.07	3d	29.75	27th.

[1] P. m. observations only.
[2] For 29 days.
[3] And other date.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

In the Hawaiian area Honolulu continued to experience prevailing east winds, though the maximum velocity was 30 miles from the southwest. This was on the 8th during what the observer termed an "unseasonable kona," which brought excessive precipitation for a short time and broke a seven-months' drouth. The total June rainfall was 1.98 inches, which is 1.06 inches above the normal. The kona was due to a depression which appeared over the islands on the 5th. The LOW moved northward and slightly westward, affecting Honolulu most on the 8th. On the 11th it had traveled northwestward to a point near 50° N. and the 180th meridian, where it shortly disappeared without the usual eastward inclination of such cyclones.

During a considerable part of the month LOWS lay over Mongolia and eastern China. One of these appeared over the Yangtse Valley on the 9th. It moved into the Eastern Sea on the 11th, and by the afternoon of the 12th, when it was central between Taiwan and southern Japan, had acquired considerable intensity. Late on the 12th and early on the 13th the American steamer *China Arrow* was experiencing gales of force 10 from NNE. to NE., in 28° 24' N., 128° E., with barometer down to 29.47 inches. During the 13th the storm crossed the Nansei Archipelago and late on that date and during the 14th and early 15th vessels off the lower and eastern Japanese coasts were experiencing northerly to northeasterly winds of force 10 and 11, with squalls of hurricane force. Among these vessels were the American steamers *President Lincoln* and *West Chopaka*. The cyclone closely

touched the eastern extremities of Hondo and Yezo, the latter on the afternoon of the 15th and, thence moving northeastward, seems shortly to have died out east or southeast of Kamchatka.

In the American Tropics the rainy season was well established at sea early in the month, especially off the Central American coast. One cyclone developed in this area. Our only information thus far received concerning it is from the Italian steamer *Duchessa d'Aosta*, which was southward bound at the time of the blow. Late on the 13th, while west of the southern part of the Gulf of Tehauntepec, this vessel ran into a moderate gale from ESE., with falling barometer. Before midnight the gale had changed to NE. by N., and increased to force 10, with pressure at 29.55 inches. At 5.30 a. m. of the 14th the barometer had risen only 0.03 inch from the lowest reading, with the wind at WSW., 7, and decreasing, in 15° N., 95° 50' W.

NOTES

South Pacific Cyclone.—According to press reports the harbor of Valparaiso, Chile, was swept by a hurricane on June 10, and much damage was done to shipping.

Indian monsoon.—The British steamer *Eurylochus*, while crossing the north Indian Ocean between Penang and Aden, experienced the southwest monsoon from June 7 to 20. On the 17th to 19th, while between 8° N., 55° E., and Cape Guardafui, the vessel reported a strong monsoon, often reaching force 8, but with "barometer following usual range."—*W. E. H.*

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

The outstanding feature of the month was its resemblence to one of the colder months of the year rather than to a normal June month; cyclonic systems developed rather more than the usual intensity and there were a large number of days when low pressure in the southeastern States, in conjunction with higher pressure to the northward, caused north to east winds and much cloudiness over the northeastern States, the Lake region and Ohio Valley, where the month was unusually cool. In the far west it was exceptionally warm, due to clear skies and abundant sunshine. Precipitation, as a rule, was deficient, although some rather small areas received more than the normal amount. The usual details follow.—*A. J. H.*

CYLCONES AND ANTICYCLONES

By W. P. DAY

Twelve LOWS were plotted, which were important enough to be identified at three successive observations, and a few of these reached moderate intensity, especially along the northern border and in southern Canada. However, there were an unusual number of slight barometric depressions of local and temporary character especially over the Southern States, which could not be easily traced from the succeeding observations.

The 9 HIGHS were mostly of the Alberta type, the pressure being considerably above the normal at Fort Simpson on the Mackenzie River during most of the month; but the HIGHS pushing southward from the latter region were only of slight or moderate magnitude.

FREE AIR SUMMARY

By L. T. SAMUELS

Free-air temperatures averaged mostly below normal, with the negative departures increasing with altitude at several of the stations. (See Table 1.)

Relative humidities averaged close to normal, while the varpor-pressure departures were mostly negative at all aerological stations.

In Table 2 it may be seen that the resultant winds were close to their normal values at all stations except Ellendale, where a pronounced northerly component prevailed as compared to the normal southerly. At this station it will be observed, the negative temperature departures increase most appreciably with altitude.

The resultant winds for the month as shown by pilot-balloon observations indicated, at the 1,000 m. level, a marked southerly component over Florida, Texas, and Oklahoma, and an equally marked northerly component over North Dakota. At the other stations east of the Mississippi River the predominant resultant direction at this level was practically west. At 5,000 m. the resultant winds were northwest over all stations west of the Atlantic coast States. In the latter they were mostly west, while over southern Florida they were southwest.

Deep easterly winds were observed on the last three days of the month to heights of 10 km. at Broken Arrow, Groesbeck, Memphis and Due West. These stations were at the time situated in the southern quadrant of a ridge of high pressure extending in an E-W direction. At Washington, D. C., on these days a light northwesterly wind extending to 8 km. was surmounted by a gale reaching 34 m. p. s. from the west-southwest. The line

dividing these two currents was exceedingly sharply defined.

The 8 a. m. and 3 p. m. pilot-balloon observations at Washington, D. C. on the 14th afford an excellent example of the diurnal variation in wind velocity with height. At these times an area of low pressure was approaching this station from the west, but only the winds below 2,200 m. showed any change during this interval. The well-known diurnal increase in wind velocity at the surface and adjacent levels and the decrease above are particularly well shown and are given in the following table:

Altitude (m.) m. s. l.	Wind velocity m. p. s.	
	8 a. m.	3 p. m.
Surface	1	4
250	2	8
500	1	7
750	3	2
1,000	5	1
1,500	8	2
2,000	9	5
2,500	10	10

Another illustration of a well-marked diurnal effect is shown in the Due West kite records of the 23d and 26th. The usual diurnal increase in the temperature lapse-rate throughout the first several hundred meters of the air column is particularly well brought out in these records. It will be noted in the following table that the nocturnal inversion resulting from radiation was entirely eliminated during the kite flight by the effects of insolation and by the time of the descent had been replaced by a super-adiabatic temperature gradient. On both of these dates this station was under the influence of low pressure and thundershowers occurred the ensuing night.

	Twenty-third				Twenty-sixth		
Time	Alt.(m.) m. s. l.	Temp. °C.	Δt 100 m.	Time	Alt. (m.) m. s. l.	Temp. °C.	Δt 100 m.
A. M.				A. M.			
8.13	217	21.9		8.18	217	24.3	
8.14	379	19.6	1.42	8.19	394	22.5	1.02
8.19	601	21.4	−0.81	8.24	606	24.4	−0.90
8.30	1,192	17.0	0.74	8.42	1,183	19.7	0.81
8.51	1,956	11.4	0.72	9.08	1,950	12.2	0.98
9.22	3,057	5.5	0.54	9.31	2,295	11.0	0.35
10.16	3,573	1.8	0.72	9.36	2,880	6.9	0.70
10.21	3,891	0.8	0.46	9.57	3,052	5.7	0.70
10.29	2,982	6.3	0.63	10.20	4,097	−0.1	0.56
11.02	1,816	13.6	0.65	10.41	4,798	−3.7	0.54
11.15	890	19.6	1.22	11.02	3,716	2.4	0.59
11.23	217	27.8		11.14	2,817	7.7	0.69
				11.25	1,933	13.8	1.05
				11.30	1,762	15.6	0.90
				11.46	1,082	21.7	1.01
				11.57	566	26.9	1.23
				P. M.			
				12.02	217	31.2	

The official in charge of Due West, in referring to an instance wherein the kite wire became greatly tangled about one of the splice wires, used for attaching secondary kites, emphasizes the strongly stratified condition of the atmosphere sometimes found. He says:

The conditions leading to these tangles may be of interest. They always happen when the atmosphere is strongly stratified; a stratum of moderate velocity near the surface above which an almost calm layer exists while farther aloft is an abrupt transition to a swiftly moving layer. Uusally this condition evolves during the kite flight for it is impossible to raise the kites through the calm layer, as this is generally of a direction opposite or normal to the lower direction. In reeling in, the kites come down one by one through the swiftly moving layer, suddenly plunge when they reach the calm layer and in most cases do a great deal of diving, upside down and rear end foremost, and at this time it is believed the turns and tangles are thrown in the wire. Flights in east winds which clockwise turn to SW. or W. aloft are bad about tangling wires and ropes and untwisting splice wires.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during June, 1926*

TEMPERATURE (° C.)

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)		Due West S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		*Washington, D. C. (7 meters)
	Mean	Departure from normal 8-year mean	Mean	Departure from normal 6-year mean	Mean	Departure from normal 9-year mean	Mean	Departure from normal 8-year mean	Mean	Departure from normal 8-year mean	Mean
Surface	23.9	−1.3	26.4	−0.4	17.8	−1.3	26.1	0.0	20.0	−2.9	20.3
250	23.8	−1.3	25.9	−0.5			25.1	0.0	19.7	−2.9	19.2
500	22.4	−0.8	23.3	−0.4	17.3	−1.5	23.4	+0.3	17.0	−2.9	18.7
750	21.4	−0.2	21.6	−0.3	15.4	−1.8	21.6	0.0	15.4	−2.6	17.3
1,000	20.1	−0.2	19.8	−0.5	13.7	−2.1	20.4	0.0	14.1	−2.3	16.1
1,250	19.0	0.0	17.3	−1.2	12.2	−2.3	19.4	+0.2	12.7	−2.1	14.7
1,500	17.6	0.0	15.5	−1.2	10.7	−2.5	18.6	+0.6	11.2	−2.2	13.4
2,000	15.0	+0.2	12.0	−1.3	7.7	−2.7	16.5	+0.8	8.5	−2.2	10.5
2,500	12.0	+0.1	9.1	−1.0	4.7	−2.9	13.2	+0.1	6.0	−1.9	7.7
3,000	8.9	+0.1	5.7	−1.3	1.6	−3.2	9.9	−0.6	3.2	−1.9	4.5
3,500	5.9	+0.2	2.1	−1.7	−1.4	−3.3	6.2	−1.6	0.4	−2.0	1.0
4,000	2.4	−0.1	−0.7	−1.7	−4.5	−3.6			−2.1	−2.1	−2.2
4,500	−0.8	−0.3	−3.4	−2.0	−8.0	−3.9			−4.6	−2.0	
5,000	−4.5	−1.0									

RELATIVE HUMIDITY (%)

Surface	70	−1	58	−3	56	−13	74	+1	62	−2	73
250	70	−1	58	−3			75	+1	62	−2	72
500	67	−4	62	−1	56	−12	75	−1	63	−2	64
750	64	−7	65	+1	58	−8	77	+2	63	−3	67
1,000	64	−6	67	+2	59	−7	72	+1	64	−3	66
1,250	62	−7	68	+2	59	−6	65	−2	64	−4	65
1,500	62	−5	69	+2	59	−4	58	−5	62	−5	65
2,000	57	−5	68	0	59	−2	49	−6	55	−8	70
2,500	51	−5	65	−2	59	0	55	+4	53	−2	57
3,000	49	−4	65	0	57	+2	54	+7	47	−4	68
3,500	48	−4	69	+6	54	+3	62	+17	41	−5	68
4,000	49	−2	73	+16	56	+3			39	+1	60
4,500	55	+6	74	+20	48	+2			37	+1	
5,000	68	+17									

VAPOR PRESSURE (mb.)

Surface	20.83	−1.85	19.04	−1.92	11.02	−4.55	24.66	+0.19	14.41	−3.47	17.64
250	20.65	−1.83	18.84	−1.78			23.70	+0.11	14.18	−3.41	16.23
500	18.29	−1.83	17.41	−0.98	10.74	−4.35	21.42	−0.15	12.33	−2.93	13.99
750	16.40	−1.77	16.47	−0.37	9.68	−3.55	19.68	+0.15	11.16	−2.75	13.23
1,000	15.21	−1.31	15.51	−0.02	8.98	−2.96	17.26	+0.16	10.40	−2.43	12.13
1,250	13.75	−1.02	12.19	−2.10	8.20	−2.58	14.66	−0.33	9.60	−2.19	10.97
1,500	12.47	−0.65	10.96	−2.10	7.45	−2.14	12.41	−0.63	8.78	−1.81	10.22
2,000	9.41	−0.66	8.15	−2.49	6.20	−1.57	9.17	−0.72	6.30	−1.87	8.79
2,500	6.60	−0.70	5.98	−2.43	5.42	−0.94	8.63	+0.69	4.78	−0.89	6.89
3,000	5.16	−0.40	4.47	−2.12	4.38	−0.54	7.41	+1.02	3.54	−0.57	5.54
3,500	3.98	−0.42	3.37	−1.77	3.35	−0.5?	7.05	+1.80	2.48	−0.16	4.87
4,000	3.23	−0.28	2.62	−1.09	2.49	−0.6?			2.26	+0.84	3.37
4,500	2.87	0.00	1.16	−1.43	1.75	−0.7?			2.04	+1.09	
5,000	2.28	+0.05									

* Naval Air Station.

Table 2.—*Free-air resultant winds (m. p. s.) during June, 1926*

Altitude, m. s. l.	Broken Arrow, Okla. (233 meters) Mean		Normal 8-year mean		Due West, S. C. (217 meters) Mean		Normal 6-year mean		Ellendale, N. Dak. (444 meters) Mean		Normal 9-year mean		Groesbeck, Tex. (141 meters) Mean		Normal 8-year mean		Royal Center, Ind. (225 meters) Mean		Normal 8-year mean		Washington, D. C. (34 meters) Mean	
(Meters)	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 31°W.	1.5	S. 6°W.	4.1	S. 75°W.	2.8	S. 73°W.	1.4	N. 50°W.	2.4	N. 63°W.	0.2	S. 16°W.	4.1	S. 3°E.	3.4	S. 76°W.	3.4	S. 60°W.	1.6	W.	0.4
250	S. 30°W.	1.6	S. 5°W.	4.2	S. 76°W.	3.0	S. 74°W.	1.5					S. 17°W.	5.0	S. 3°E.	4.1	S. 73°W.	3.8	S. 54°W.	1.7	N. 79°W.	1.5
500	S. 14°W.	3.3	S. 10°W.	5.5	S. 80°W.	3.9	S. 79°W.	2.2	N. 57°W.	2.4	N. 71°W.	0.3	S. 18°W.	6.2	S. 3°W.	5.4	S. 77°W.	6.2	S. 57°W.	3.0	N. 82°W.	2.7
750	S. 14°W.	3.4	S. 14°W.	6.1	S. 82°W.	4.5	S. 75°W.	2.8	N. 58°W.	2.5	S. 33°W.	0.7	S. 19°W.	6.5	S. 6°W.	5.8	S. 79°W.	7.4	S. 60°W.	4.1	N. 34°W.	6.7
1,000	S. 57°W.	5.4	S. 24°W.	6.3	S. 84°W.	5.6	S. 80°W.	2.9	N. 63°W.	3.1	S. 45°W.	1.3	S. 26°W.	6.2	S. 9°W.	6.2	S. 85°W.	8.0	S. 70°W.	4.8	N. 77°W.	4.8
1,250	S. 41°W.	3.2	S. 27°W.	6.3	S. 83°W.	6.5	S. 82°W.	3.6	N. 67°W.	3.6	S. 62°W.	1.9	S. 23°W.	5.4	S. 10°W.	6.4	N. 88°W.	9.5	S. 77°W.	5.5		
1,500	S. 55°W.	3.3	S. 32°W.	6.4	S. 83°W.	7.4	S. 84°W.	4.5	N. 60°W.	4.8	S. 68°W.	2.4	S. 32°W.	4.9	S. 12°W.	5.9	N. 83°W.	9.6	S. 85°W.	5.5	N. 67°W.	7.5
2,000	S. 66°W.	5.5	S. 38°W.	6.6	S. 81°W.	7.9	S. 86°W.	6.2	N. 57°W.	6.5	S. 76°W.	3.6	S. 27°W.	3.6	S. 12°W.	5.5	N. 74°W.	12.1	S. 88°W.	8.0	N. 81°W.	8.6
2,500	S. 68°W.	5.4	S. 40°W.	6.7	S. 79°W.	9.5	S. 84°W.	6.6	N. 61°W.	8.4	S. 80°W.	5.5	S. 8°E.	3.0	S. 12°W.	5.3	N. 70°W.	15.1	S. 85°W.	9.5	N. 89°W.	10.6
3,000	S. 67°W.	7.6	S. 41°W.	6.5	S. 82°W.	9.8	S. 86°W.	8.4	N. 59°W.	10.9	S. 85°W.	7.5	S. 24°E.	4.6	S. 14°W.	5.4	N. 64°W.	15.5	S. 89°W.	10.8	N. 86°W.	11.1
3,500	S. 68°W.	8.8	S. 48°W.	6.9	W.	12.0	S. 84°W.	9.7	N. 58°W.	13.4	S. 87°W.	9.4	S. 26°E.	5.6	S. 6°W.	5.6	N. 59°W.	12.2	S. 89°W.	10.8	N. 85°W.	10.2
4,000	S. 73°W.	10.0	S. 63°W.	7.4	W.	9.3	S. 84°W.	9.5	N. 69°W.	13.5	S. 89°W.	11.7					N. 53°W.	14.4	N. 82°W.	13.0	N. 84°W.	11.1
4,500	S. 89°W.	10.6	S. 88°W.	8.4	W.	13.0	N. 70°W.	13.1	N. 61°W.	18.0	N. 82°W.	13.4					N. 68°W.	18.0	N. 86°W.	9.5	W.	10.4
5,000	S. 45°W.	10.0	N. 83°W.	11.2	W.	14.0	N. 70°W.	10.7	N. 45°W.	13.0	N. 70°W.	14.2					N. 68°W.	18.0	N. 42°W.	19.4	N. 88°W.	16.0

THE WEATHER ELEMENTS

By P. C. Day, In Charge of Division

PRESSURE AND WINDS

On the whole June, 1926, was without marked features and over much of the thickly populated portions of the Middle and Eastern States it was pleasantly cool during the greater part, though mainly not sufficiently so to seriously interfere with seasonal crop development.

Like most of the months since the beginning of the year the weather continued warmer than normal in the more western districts and distinctly cool in the eastern and southern portions.

The pressure distribution was not abnormal and cyclones were confined mainly to the northern districts east of the Rocky Mountains, generally passing over the Great Lakes, where several developed into storms of considerable importance.

No cyclones of importance entered the United States from the far Northwest, though two or more appear to have had their origin during the second decade in British Columbia, and maintained their identity as moderate depressions moving eastward across the country by way of the Great Lakes and into the St. Lawrence Valley. There were only slight evidences of cyclonic activity in the Gulf and South Atlantic States.

There was little storm activity in the central Plains and to the eastward save about the 12th to 15th when a moderate cyclone moved from the middle Rocky Mountains eastward to New England and the Middle Atlantic States, attended by the most important and extensive precipitation of the month. Rains occurred in portions of the Great Plains, and there were moderate to heavy falls in the central valleys and over most eastern districts. Important precipitation also occurred on the 5th and 6th over the Gulf States and along the Atlantic coast to southern New England and on the 16th and 17th when some heavy local falls occurred in the lower Missouri and upper Mississippi Valleys and in southern Florida. Rather general rains occurred over the Gulf and South Atlantic States on the 20th and 21st, and precipitation was rather general over the northern States east of the Rocky Mountains on the 21st and 22d, and again over the Gulf and Atlantic Coast States on the 23d and 24th, and on the 27th and 28th, though there was little evidence of cyclonic action on any of these dates.

Anticyclones of importance were notably infrequent and they exerted no important influence on the weather of the month save on the 16th and 17th when high pressure caused sharp temperature falls in the Atlantic Coast States, and similar conditions existed on the 20th and 21st, and high pressure caused a rather important lowering of the temperature over the central valleys and generally to the eastward on the 26th and 27th.

Pressure averaged somewhat higher than normal for June over the western half of both the United States and Canada and lower over the eastern half of both countries, though the changes from normal were not unusually large. Compared with the pressure for the preceding month, it was higher from the western Canadian Provinces southeastward to Texas, and over the middle Mississippi and Ohio Valleys and the Atlantic Coast States. It was lower than in May west of the Rocky Mountains, save for a small area in the far Northwest, it was lower, also, in portions of the middle Gulf States and from the Great Lakes to the Canadian Maritime Provinces.

Moderately high pressure over the Southeastern States during much of the month favored southerly winds in the Mississippi Valley, Great Plains and Gulf States, and southwest to west winds from the upper Mississippi Valley eastward. Over other parts of the country winds were greatly diversified, though there was a general tendency toward a cyclonic circulation around the Great Basin.

Local wind, hail or other damaging storms were reported on most days of the month, but were confined largely to the area between the Great Plains and Appalachian Mountains. An unusually severe thunderstorm with heavy lightning damage occurred at San Francisco, Calif., on the 7th. In the main, however, damages from such storms were moderate and but few lives were lost.

The details concerning the more important storms of the month appear as usual at the end of this section.

TEMPERATURE

As has been the case for a number of months past, the average temperatures were above normal over the western half and below over the eastern, the center of most pronounced heat covering the Plateau and Pacific Coast States, where the average departures ranged from 4° to 9°, and the means at a number of points in the area were among the highest of record for June. On the other

hand, temperatures were decidedly low for June from the Missouri Valley eastward to the Atlantic coast, the averages in most sections ranging from 4° to 6° below normal, and in portions of the Great Lakes region and northeastern States it was the coolest June of record, some stations reporting temperatures below normal on all except one or two days.

The first and last weeks were distinctly warm west of the Rocky Mountains, the positive departures ranging up to 10° or 15° per day at points in the Plateau region. During these weeks it was decidedly cool over most central and eastern districts, the negative departures ranging from 4° to 9° per day over the Great Lakes and south and east of them. The second week was mainly warmer than normal, save over portions of the Great Lakes and near-by areas, while the third week was mainly cooler than normal except in portions of the South and far West, where temperatures were slightly above normal.

Maximum temperatures in excess of 100° were reported from all States except those from the Lake region and Ohio Valley eastward, the maximum, 124°, occurring in southern California, and readings of 110° to 120° were reported from a number of the western Mountain and Plains States. The warmest periods were mainly during the last decade, notably about the 26th to 28th from the Great Plains westward, and on the last two days of the month, from the Great Lakes eastward and southeastward, save in New England where the 25th was the warmest day. Over the Ohio Valley and thence south and southeast the warmest days were about the 12th to 15th. At a few points in the far West the maximum temperatures were the highest of record for June.

The lowest temperatures occurred mainly during the first week from the Great Plains eastward. West of the Plains they occurred mostly during the second decade. Minimum temperatures were below freezing in all northern States and generally over the western mountains, the lowest, 15°, occurring in Colorado.

The persistence of unusual warmth over the more western portions of the United States during the present year so far, and of unusual coolness over the eastern half of the country from March to June, inclusive, and over the more northeastern States since February, inclusive, present conditions probably without parallel in some particulars during the past 50 years.

From January to June, inclusive, the temperature at Havre, Mont., has averaged 8° per day above the normal, a condition that has not previously existed at that point in nearly 50 years of authentic record. Similar conditions have existed during the year so far over many other western districts, the period of excessive heat including, in some sections, November and December of 1925. As a result the season has been greatly advanced and many fruits and other agricultural products have ripened at unusually early dates.

Over much of the eastern part of the country reverse conditions have prevailed and crop growth has been greatly delayed; in some cases, particularly in the more northeastern districts, conditions have been similar to those of 1917, though the area of greatest cold was probably not so extensive as in that year. As a result of the continued deficiency in temperatures, agricultural operations have been much delayed and crop growth over some eastern and northeastern districts has been greatly retarded.

PRECIPITATION

The general lack of precipitation which has been so widespread during much of the present year continued during June, particularly from the lower Mississippi Valley northeastward to New England and generally over the Missouri Valley and from the Rocky Mountains westward. Not more than one-fifth of the States had precipitation above normal, and in these cases the excess was mainly trifling, while the deficiencies were large over extensive areas. In a few instances the total precipitation was nearly or quite the least of record for June.

Despite the general deficiency in precipitation the important crops over no large areas have been seriously curtailed for want of moisture.

This has seemingly been due to fairly good distribution, both geographically and in the matter of time, of such rainfall as has occurred, and in most of the East to the prevalence of temperatures below normal.

SNOWFALL

Measurable amounts of snow were reported at exposed points in the Rocky Mountain regions from Colorado northward, with maximum falls of 3 to 4 inches at the highest elevations. Traces of snow or slightly more occurred in the Lake Superior region and in the mountains of northern New York.

RELATIVE HUMIDITY

For the country as a whole the relative humidity was remarkably low. This applies not only to the unusually warm western area but to the more easterly sections, where the weather was so persistently cool.

Only a few local areas in the Southern States, in the middle Rocky Mountains, and along the immediate Pacific coast had relative humidity percentages appreciably higher than normal for June.

SEVERE LOCAL HAIL AND WIND STORMS, JUNE, 1926

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual Report of the Chief of Bureau.]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Lincoln County, Okla. (southern part of).	1	1.30–2 a.m.	[1]4 mi.			Hail	Severe crop damage; other losses heavy	Official, U. S. Weather Bureau.
Kossuth County, Iowa	1	9 a. m.	[1]6 mi.			Wind	Crops damaged about 25 per cent	Do.
Racine County, Wis	1	P. m.		1		do	Heavy property damage reported	Do.
Jewell, Ottawa, Republic, and Cloud Counties, Kans.	1	6–7 p. m.	[1]2–10 mi.		$225,000	Hail	Growing wheat and oats beaten to ground; many window panes broken; auto tops pierced.	Do.
Pawnee County, Kans	1	7 p. m.	[1]3–4 mi.		75,000	do	Wheat damaged 10 to 100 per cent; many windows broken in Larned.	Do.
Cleveland, Okla	2	6 p. m.			14,000	Rain and hail	Property and crop damage considerable	Do.
Northwest Scotts Bluff and southwest Sioux Counties, Nebr.	3	4 p. m.	[1]1–2½ mi.		36,000	Hail	Considerable damage over path 10 miles long	Do.
Taylor County, Tex	3	5.15 p. m.	[1]2–8 mi.		200,000	do	Crops, roofs, and glass damaged	Do.
Humphreys County, Tenn. (northeast part of).	3	P. m.			9,000	do	Crops injured	Do.
Franklin, Tenn. (northeast part of).	3	do			45,000	do	Heavy losses, principally to crops	Do.
Madison, Ala	3				1,000	do	Crop damage reported	Do.
Memphis, Tenn	3				3,900	Thunderstorm	Telephone, electric, and power services crippled	Do.
Monroe, Tex	4	5.30 p. m.	1,760			Hail	Crops a total loss	Do.
San Francisco, Calif	7	4.45–5.40 a. m.			100,000	Thunderstorm	Severe damage by lightning	Do.
Cumberland County, N. J. (parts of).	7				150,000	Hail	Truck, fruit, and plant beds ruined over path 3 to 4 miles long.	Do.
Manchester, Ala	7				1,000	do	Crops injured	Do.
Plattsburg, Mo. (west of)	7	P. m.	1,750		5,000	do	Damage confined to growing crops	Do.
Honolulu, T. H.	8	4–5 a. m.			470	Whirlwind	Two houses unroofed and a fence blown down	Do.
Pratt and Kingman Counties, Kans.	8	3 p. m.	[1]3 mi.			Hail	Wheat damaged 40 to 50 per cent	Do.
May, Okla. (7 miles southwest of).	8	3.30 – 4.30 p. m.	[1]3½ mi.			do	Crop destruction over a path 6 miles long	Do.
Dickinson County, Kans	8–9	Midnight				Violent wind	Farm buildings damaged	Do.
Leesburg (near), Ala	9				1,000	Hail	Some crop damage	Do.
Abilene (near), Kans	9	Midnight				Violent thunderstorm.	Barns, garages, and porches damaged; trees uprooted.	The Chapman Advertiser (Kans.).
Pocahontas County, Iowa	10	3.30 – 4.30 p. m.			31,500	Hail and wind	Crops and buildings damaged; livestock killed	Official, U. S. Weather Bureau.
Thomasville (near), Ga	10					Thunderstorm and hail.	Farm structures damaged and a mule killed	Do.
Bremer, Buchanan, Hancock, Ida, Pocahontas, and Wright Counties, Iowa.	11	3–9.30 p. m.	[1]1–4 mi.		70,000	Hail and wind	Chief damage to crops by hail	Do.
Grant, Lafayette, and Iowa Counties, Wis.	11	P. m.			16,500	Thundersquall	Some property damage; livestock killed. Tornado cloud seen near Darlington.	Do.
Archer, Wyo	12	1.30 – 5.30 p. m.				Heavy rain and hail.	All crops injured	Do.
Dallas County, Iowa	12	8 p. m.		1	7,000	Electrical and hail	Buildings damaged by lightning; crops by hail	Do.
Mercer, Woodford, and Fayette Counties, Ky.	12					Thundersqualls	Buildings, timber, crops, and wire systems much damaged.	Do.
Northeastern Missouri	12	P. m.			7,000	Thunderstorms	Some farm buildings damaged; small outhouses wrecked; a few head of livestock killed.	Do.
Polk County, Iowa	13	12 a. m.			50,000	Hail and rain	Crop damage over an area of 50 square miles	Do.
Murray County, Okla. (eastern part of).	13	3.30–3.45 p. m.	[1]2 mi.			Hail	Crops and other property considerably damaged	Do.
Wright County, Iowa	13	4 p. m.	[1]2 mi.		2,000	do	Some crop injury; minor property damage	Do.
Steinauer, Nebr	13	4.30 p. m.	116			Small tornado	Character of damage not reported. Path 1 mile long.	Do.
Neodesha, Kans	13	6 p. m.	[1]12 mi.			Violent wind	Many barns and other small buildings damaged; power and telephone lines prostrated.	Do.
Chicago, Ill., and vicinity	13	P. m.		2		Thunderstorm	Heavy damage by flooding; about 35 fires attributed to lightning; numerous traffic blockades; a number of persons injured.	Do.
Topeka, Kans. (5 miles north of).	13					Thundersquall	Considerable damage at County Poor Farm	Do.
Abilene, Tex	14	3.30 p. m.	[1]5–6 mi.		60,000	Hail	Crops, buildings, and much glass damaged over path 20 miles long.	Do.
Roosevelt, Okla	14	6 p. m.	880		2,000	do	Damage chiefly to crops. Path 4 miles long	Do.
Davidson, Okla., and vicinity.	14	6.20 p. m.	[1]3 mi.		90,000	Heavy hail	Nearly every home in path damaged; crop loss about $50,000.	Do.
Goltry, Okla., and vicinity	14	6.30 p. m.	[1]2 mi.		1,000	Hail	Crops injured	Do.
Snyder, Okla. (6 miles southwest of).	14	7.45 p. m.	1,760		5,000	do	Destruction confined to crops. Path 2 miles	Do.
Cheyenne, Wyo	14	10.20–11.05 p. m.	1,760		140,000	Heavy hail	Roofs pierced; glass broken; streets damaged; path 6 miles long.	Do.
Hummeltown, Pa	14	P. m.			20,000	Hail and wind	Many window panes broken in residences, churches and greenhouses; gardens and farm crops injured.	Do.
Parkersburg, W. Va	14					Thunderstorm and wind.	Overhead wires considerably damaged; several hundred telephones out of order.	Do.
Port Huron, Mich	14					Electrical	Electric generating plant struck by lightning causing thousands of dollars damage.	Do.
Royal Center, Ind	14				5,000	Wind and hail	Buildings, trees and wheat damaged; some evidence of tornadic action.	Do.
Arcola and Carpenter, Wyo	14–15	11.30–12.30 p. m.	[1]7 mi.		4,000	do	About one-sixth of all crops destroyed	Do.
Grantville (near), Kans	15					Tornado	No damage as cloud did not reach ground	Do.
Lancaster County, Pa. (northern part of).	15	3 p. m.			100,000	Small tornado	Considerable damage east of Paradise; many buildings leveled, others unroofed; most severe damage occurred at Vintage.	Do.
Lingle, Wyo	15	do	[1]10 mi.		5,000	Hail and rain	Sugar beets injured	Do.
Torrington, Wyo. (2 miles southwest of).	15	3.30 p. m.	67		11,000	Tornado	Several buildings damaged; 26 persons injured	Do.

[1] "Mi." signifies miles instead of yards.

Severe local hail and wind storms, June, 1926—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
North Platte Valley, Nebr., from Bayard westward to State line.	15	3–11 p. m.	[1]3–5 mi.		500,000	Hail	Hay, corn, grains, and sugar beets damaged	Official, U. S. Weather Bureau.
Helena and Goltry, Okla	15	5 p. m.	[1]6 mi.		200,000	do	Extensive crop loss; other losses, including poultry, estimated at $50,000. Path 10 miles.	Do.
Tipton, Okla. (west and north of).	15	do			50,000	do	Heavy crop damage; minor property loss	Do.
Washita County, Okla	15	6 p. m.				do	Considerable crop injury	Do.
Pottstown, Pa	15	P. m.			2,000	Electrical	Church destroyed by lightning	Do.
Yuma (near), Colo	15	do				Tornado and hail	Several buildings demolished	Do.
Lincoln County, Nebr. (north part of).	16	1.30 p. m.	1,760			Hail	Small pigs and chickens killed; windows broken; severe damage in places.	Do.
Clarinda, Iowa	16	3 p. m.	75	2	250,000	Tornado	Damage chiefly to buildings; 24 persons injured. Path 6 miles long.	Do.
Richland Center, Wis	16	3.30 p. m.	440		10,000	Heavy hail	Crops ruined; windows pierced; shrubbery stripped.	Do.
Harrison (north part of) and Mercer Counties, Mo. (northwest part of).	16	4 p. m.	440–2,640		100,000	Tornado	Loss of household effects, livestocks and farm implements heavy. Some crop injury.	Do.
Taylor and Ringgold Counties, Iowa.	16	do	440–880		115,000	Tornado and hail	Building and crop damage extensive; 5 persons injured.	Do.
Topeka (near), Kans	16	5.08 p. m.				Two tornadoes	Very light damage	Do.
Blackwell, Okla., and vicinity.	16	6 p. m.	[1]3 mi.		10,000	Hail	Crops damaged over path 8 miles long	Do.
Ford County, Kans. (west part of).	16	8 p. m.	[1]10 mi.		200,000	do	Growing wheat damaged	Do.
Adams County, Ill	16	9 p. m.	75–880		5,000	Wind and rain	Basements flooded; some damage by lightning	Do.
Cheyenne Wells, Colo	16				35,000	Hail	Character of damage not reported	Do.
Climax (near), Kans	16	P. m.			(²)	Tornado	do	Do.
Eureka, Kans. (12 miles west of to 12 miles north of).	16	do			100,000	do	Storm passed over sparsely settled country; a few residences, outbuildings and oil drilling outfits damaged.	Do.
Anson, Tex	17	4 p. m.	[1]2 mi.		4,000	Hail	Crop and glass damaged. Path 5 miles	Do.
Estancia (near), N, Mex	17	5.45–6 p. m.	[1]3–4 mi.			Severe hail	Many crops destroyed over long path	Do.
Lamesa, Tex	17	6 p. m.	552			Hail	Crops and buildings damaged. Path 15 miles	Do.
Fowler, Colo., eastward to Kansas State line.	17	P. m.			200,000	do	Storm followed valley of Arkansas River; grain ruined; fruit damaged about 75 per cent; roofs badly pierced.	Do.
Tahoka, Tex	17		[1]4 mi.			do	Crops a total loss	Do.
Hope, N. Mex	18	2.15 p. m.			2,000	do	Apple orchards injured	Do.
Espanola, N. Mex	18	P. m.	[1]3 mi.			Wind, rain, and hail.	Fruit and gardens injured; railroads washed out in places.	Do.
Woodford County, Ill	20	4–5 p. m.	2,640			Hail	1,200 acres of wheat and oats reported total loss, 1,500 partial loss.	Do.
Mitchell County, Kans	20	5–6 p. m.				Tornado	Minor damage, sparsely settled country	Do.
Ellsworth and Saline Counties, Kans.	20	7.30 p. m.	33		40,000	do	All building on 1 farm demolished	Do.
Pottawatamie to Audubon County, Iowa.	20	7.30–8 p. m.	440		20,050	Wind	Damage chiefly to buildings	Do.
Seneca (near), Kans	20	8 p. m.				Tornado	Farm buildings and telephone lines damaged	Do.
Severance (near), Kans	20	do	200		1,200	do	do	Do.
Wichita, Kans	20	11 p. m.	16–67		15,000	Violent wind	Planes and hangars damaged	Do.
Lamesa (near), Tex	20		[1]3 mi.			Hail	Total crop damage over path 10 miles long	Do.
Central and southeastern counties, Wisconsin.	21				3,550	Wind	Minor damage over wide area; about $2,000 damage in Milwaukee.	Do.
Clanton (near), Ala	22				1,000	Hail	Crops injured	Do.
Texarkana (near), Tex	22				100,000	do	do	Do.
Finney, Gray, Haskell, Stevens, Seward, Meade, Ford, and Kiowa Counties, Kans.	23	9. p. m.			600,000	do	Great amount of growing wheat damaged 10 to 100 per cent. Loss heaviest near Copeland and Moscow.	Do.
Summerville, Ga	23				1,000	Wind and rain	Some barns destroyed and farm animals killed	Do.
Onalaska and North La Crosse, Wis. (near).	24	1–2 p. m.	1,760			Heavy hail	Corn considerably damaged	Do.
Tajique (near), N. Mex	24	3 p. m.				Tornadolike cloud	No damage reported	Do.
Washington County, Md. (northeast part of).	24	6–7 p. m.	[1]2–4 mi.		90,000	Hail	Crops and fruits severely damaged	Do.
Dunbarton (near), Wis	24	9.45 p. m.	880–1,320			Heavy hail	Gardens and soy beans badly injured	Do.
Springbank (near), Miller County, Ark.	24	Midnight	[1]7 mi.		100,000	do	Crops destroyed	Do.
Burnett (near), Wis	24					do	Partial loss of corn and pea crops on some farms	Do.
Calhan, Colo	25	2–7 p. m.	1,760			Hail	Crops destroyed from one-tenth to total in path	Do.
Griggsville, Ill	25	3.30 – 3.50 p. m.	[1]3 mi.		60,000	do	Apple and other fruit crops severely damaged; path 6 miles.	Do.
Cheyenne Wells, Colo	25	5 p. m.	[1]2 mi.		10,000	do	Character of damage not reported	Do.
Laclede County, Mo. (parts of).	25	P. m.				Thunderstorm and hail.	Crops in path almost totally destroyed; some poultry killed; minor damage to buildings.	Do.
Campstool and Hereford Ranch, Wyo.	25				12,000	Hail	Crops severely injured	Do.
Muncie, Ind	25					do	Fruit trees damaged	Do.
Chacon, N. Mex	26	12.35 p. m.	2,640		500	Heavy hail	Crops badly injured	Do.
Auburn, N. Y., and vicinity.	26	P. m.				Hail	Windows, trees, and crops damaged	Do.
Ontario County, N. Y., Bristol northeast to Orleans.	26	do	[1]5 mi.		200,000–500,000	do	Crops severely damaged, some totally; windows and trees broken.	Do.
Syracuse, N. Y., and vicinity.	26	do				do	Loss of 50 to 60 per cent of apple crop	Do.
Thermopolis (near), Wyo	26			1		Electrical	Two persons stunned and two dogs killed by lightning.	Do.
Thomaston, Ga	26–27					Heavy hail	Land and crops considerably damaged	Do.
Cowies, Nebr	29	5 p. m.	[1]2 mi.		50,000	Hail	Heavy property damage. Path 7 miles	Do.
Tecumseh, Nebr	29	7–7.45 p. m	[1]2 mi.		10,000	Hail and wind	Character of damage not reported. Path 6 miles long.	Do.
Sage, Wyo	29			1		Electrical	A horse and some sheep also killed by lightning	Do.
Sikeston, Mo., and vicinity	30	2.40–5 p. m.			500,000	Wind, rain and hail.	Extensive crop and property damage	Do.
Pulaski County, Ill	30	P. m.	880		50,000	Hail and wind	Heavy crop damage, chiefly to peaches; minor property loss. Path 2 miles.	Do.
Barnesville (near), Ga	30		880		5,000	Heavy hail	Crops damaged	Do.
Drill Center, Wyo. (8 miles southeast of).	30					Hail	Range cut and beaten badly	Do.
Ideal, Ga	30				3,000	do	Corn, cotton, tobacco, melons, and peaches severely hurt.	Do.

[1] "Mi." signifies miles instead of yards.   [2] Damage included in that of storm near Eureka on the 16th.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

On the 1st, small-craft warnings were displayed from Boston to Wilmington in connection with a disturbance of considerable intensity over Ontario, and again on the 5th from Nantucket to Norfolk. On the evening of the 6th, when a disturbance of marked intensity was over Lake Superior and a second center of increasing intensity was south of Nantucket, storm warnings were ordered from Sandy Hook to Boston for fresh-to-strong northeast, shifting to strong southwest, winds. Winds were fresh to strong but did not reach gale force. On the 15th small-craft warnings were ordered from Delaware Breakwater to Portland, Me., for fresh-to-strong shifting winds.

Warnings for light frost were issued on the 3d for western New York and western Pennsylvania and on the 20th for Vermont, New Hampshire, and the interior of Maine.—*R. H. Weightman.*

CHICAGO FORECAST DISTRICT

Storm warnings for the Great Lakes.—For a summer month June, 1926, was unusually stormy on the Great Lakes, no fewer than six disturbances of major importance having occurred. Either storm or small-craft warnings had to be issued on more than one-half the days of the month.

On the morning of the 1st a strong disturbance from the Northwest was central north of Lake Huron. Southwest storm warnings were issued at that time for Lake Ontario and extreme eastern Erie, and small-craft warnings were advised for the remainder of Lake Erie, also for Lake Huron and extreme eastern Lake Superior. Small-craft warnings were continued on the following day on all the Great Lakes, since an area of high pressure had built up over the Northwest in the rear of the disturbance, thus increasing the gradient.

Another northwestern disturbance occurred on the 6-8th, for which general warnings were issued on the night of the 5th. As it reached the Lake Region it underwent a marked development, and moved so slowly across the Lakes that its influence covered a period of three days.

The third disturbance reached Lake Michigan on the night of the 13–14th. This storm appeared to have developed as early as the 7th over the interior of British Columbia, whence it moved slowly eastward and southward to the Middle West by the 11th. Thereupon one section passed eastward without storm development, while the second section continued to develop until the evening of the 13th, when it began to move northeastward from Kansas. This storm was most severe over Lake Michigan, where northeast and north gales occurred on the night of the 13–14th. The warnings issued in this connection were general in scope.

The next storm developed over the Rocky Mountain Plateau, and it appears to have been associated with its immediate predecessor. It reached the Upper Lake Region on the 16th and the Lower Lake Region the next day. Northwest warnings were issued for the Upper Lakes, and southwest warnings for the Lower Lakes. After reaching the Great Lakes, however, the storm lost force.

Storm No. 5 was one of apparently Rocky Mountain Plateau origin. The center moved eastward across the northern Great Plains, reaching the Upper Lakes on the night of the 20–21st. Thereupon a marked increase in intensity occurred. The warnings issued for this storm were general, and either verifying or near-verifying winds occurred throughout the Great Lakes Region.

The final disturbance came from the far Northwest. In fact, it is easy to trace the path backward to the North Pacific Ocean and Alaska. Small-craft warnings were issued. A few verifying velocities occurred, but these were mostly squall winds of short duration in connection with thunderstorms.

Frost warnings.—The month was cool over virtually the entire forecast district, but particularly in the eastern portion, where the mean temperature was among the lowest of record in recent years. Frost warnings were issued on the 2d, 3d, 4th, 8th, 18th, 19th, and 25th for more or less limited parts of the district. With one or two exceptions, these warnings were confined to the States of Minnesota, Wisconsin, and Michigan. The greatest utility of the warnings was in connection with the protection of the Wisconsin cranberry crop.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT

Temperatures averaged near normal. Precipitation was decidedly irregular, being mostly above normal except in the extreme eastern portion of the district, where there was a marked deficiency. Much of the rain fell while areas of high pressure were advancing southeastward to the district or passing eastward over the upper Mississippi Valley.

No warnings were issued or required—*R. A. Dyke.*

DENVER FORECAST DISTRICT

Temperatures averaged well above normal throughout the district, except at Yellowstone Park and Roswell; in western Utah the excess amounted to more than 4° daily. Precipitation was deficient everywhere except at Cheyenne, where an unusually heavy downpour, accompanied by destructive hail, occurred on the night of the 14th, causing the monthly total to run more than three inches above normal. Droughty conditions prevailed in Montana until the 12th or 13th; thereafter showers were rather frequent. The usual summer condition of relatively low pressure over the Rocky Mountain and Plateau regions, with ill-defined centers of activity, prevailed until the 20th, when high pressure entered from the Pacific over Washington and Oregon, spreading southeastward and dominating the weather in this district until the 25th, when a deep LOW appeared over Alberta. Its passage eastward along the Canadian border was attended by unusually high temperatures over most of the district on the 25th, 26th, and 27th.

The only warnings issued were fire-weather warnings on the evening of the 13th and again on the morning of the 15th, for unusually strong winds in the forested regions of Arizona and New Mexico; both were justified.—*E. B. Gittings, jr.*

SAN FRANCISCO FORECAST DISTRICT

At the beginning of the month the Pacific high-pressure area, which had been weak and vacillating during April and May, showed indications of assuming normal proportions and stability. An off-shoot from it, pushing inland over the States of Oregon and Washington, called for predictions of rising temperature in those States on the 1st and this was amplified by the Seattle official into particular fire-weather advices for Washington specifying

the probability of decreasing humidity during the ensuing 48 hours. These advices were fully verified. In California the fire hazard grew slowly more acute, but as warnings of it had been issued on the 30th of May, no further special warnings were required. The fire hazard in Oregon and Washington was reduced somewhat on the 4th by the passage of a Canadian disturbance which raised humidities and lowered temperatures in those States, but this was quickly followed by a recurrence of high pressure and rising temperatures on the 5th which resulted in excessively warm weather throughout the interior of northern California and southwestern Oregon, and temperatures generally well above normal in other parts of Oregon, and in Washington and Idaho. Temperatures moderated very decidedly in California on the 7th due to the development of a depression over the Plateau. This depression gathered energy and moved northward bringing cooler weather to the remainder of the district on the 8th and 9th.

This type persisted for two weeks when the pressure fell in the Gulf of Alaska and the sub-permanent oceanic HIGH reverted to a southwest-northeast position between the Pacific States and Hawaii. At the same time the pressure rose over the North Pacific States calling for fire-weather warnings for northern California on the 20th. The fire hazard grew steadily more serious in that part of the State from then on, and it increased likewise in Oregon, Washington, and Idaho, the situation in the last-named States being adequately covered by the forecasts issued at San Francisco, Portland, and Seattle. Falling pressure over the northern Plateau and British Columbia brought lower temperatures and higher humidities to a large part of the district on the 29th and 30th, but severe lightning storms on those days, ignited hundreds of fires, and at the close of the month an unusually large number of serious conflagrations was being fought in the Sierra Nevada and Siskiyou mountains of California. Particular reference was made to the probability of thunderstorms in the mountains of California in the district forecasts of the 27th, 28th and 29th.—*T. R. Reed.*

RIVERS AND FLOODS

By H. C. FRANKENFIELD

The few floods which occurred in important rivers during June were generally well forecast and without damage of any kind.

An extensive crevasse occurred on the 14th in the levee of the Imperial Irrigation District south of the Pescadero Dam in the Colorado River, resulting in the flooding of a considerable area of land about Volcano Lake. No report of the extent of the damage was received.

A serious local flood, due to excessive precipitation in a thunderstorm, took place on the 11th in the Pecatonica River of north-central Illinois. One man was drowned and considerable unreported damage occurred to lowland crops in a restricted area.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
Mississippi drainage	*Feet*			*Feet*	
Tippecanoe, Norway, Ind	6	13	14	6.6	June 14
Mississippi, Louisiana, Mo	12	12	12	12.0	12
Des Moines, Ottumwa, Iowa	10	15	16	10.5	16
Illinois:					
Peru, Ill	14	13	21	14.7	16,18,19
Beardstown, Ill	14	17	30	15.4	21
Pearl, Ill	12	17	23	12.9	21
Grand:					
Gallatin, Mo	20	17	17	23.7	17
Chillicothe, Mo	18	15	21	24.4	18
Grand, Thompsons Fork, Trenton, Mo	20	18	18	20.6	18
Canadian, Logan, N. Mex	4			6.6	19
West Gulf drainage					
Trinity:					
Dallas, Tex	25	2	6	28.0	5
Trinidad, Tex	28	7	10	30.7	9
Rio Grande, San Marcial, N. Mex	2	(¹)	22	4.5	May 27, 28
Pecos, Pecos, Tex	11	1		13.4	June 1, 2
Pacific drainage					
Colorado:					
Fruita, Colo	12	3	3	12.0	3
		5	9	12.5	8
Parker, Ariz	7	(¹)	(²)	10.2	12–13
Eagle, Eagle, Colo	5	3	9	5.6	8
		13	13	5.3	13
		15	15	5.5	15
Gunnison, Delta, Colo	9	1	13	10.0	5

¹ Continued from last month.   ² Continued at end of month.

MEAN LAKE LEVELS DURING JUNE, 1926

By UNITED STATES LAKE SURVEY

[Detroit, Mich., July 3, 1926]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes [1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during June, 1926:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	600.50	578.41	571.22	245.31
Above or below—				
Mean stage of May, 1926	+0.32	+0.27	+0.05	−0.06
Mean stage of June, 1925	−0.72	−0.05	+0.04	−0.11
Average stage for June, last 10 years	−1.67	−2.15	−1.48	−1.32
Highest recorded June stage	−2.93	−5.19	−3.30	−3.33
Lowest recorded June stage	−0.72	−0.05	+0.04	+0.42
Average departure (since 1860) of the June level from the May level	+0.27	+0.23	+0.18	+0.14

[1] Lake St. Clair's level: In June, 1926, 573.79 feet.

THE EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS JUNE, 1926

By J. B. KINCER

General summary.—At the close of May, soil moisture was deficient over a considerable area in the central-northern portion of the country between the upper Mississippi Valley and the Rocky Mountains, and it was

much too dry for good growth of vegetation in the interior of the Southeastern States. Otherwise, moisture conditions were mostly favorable. The drought in the Southeast continued until after the middle of the month, but generous rains the latter part brought relief and thereafter crops made good growth in that section. In the central-northern portion comparatively good rains brought considerable relief about the middle of the month, but, in general, at its close moisture was still needed over a rather wide area of the Northern Plains.

It was too cool for good growth, especially for warm-weather crops, over the northeastern quarter of the country from the middle Mississippi and Ohio Valleys northward and northeastward, and progress was generally slow with the season continuing late. In the South, while it was occasionally too cool for good growth, temperatures were more favorable and crops made fair to good progress, except in the southeastern drier sections. In the Southwest conditions were generally favorable, as soil moisture was mostly ample and temperatures moderate. It was too dry in the far Northwest and the prevailing high temperatures were unfavorable for dry-land crops.

Small grains.—Except in the north-central Great Plains, the weather during June was generally favorable for winter wheat, and the crop made satisfactory progress throughout the principal producing area. Over the central and eastern portions of the belt generous rains about the middle of the month were very beneficial, particularly in northern districts, but in the northwestern portion, especially in northwestern Kansas and in Nebraska, moisture continued insufficient, and the crop was badly damaged by the drought. Exceptionally good harvest weather prevailed, and this work made rapid progress, at a little later date, however, than usual in the eastern portion of the Wheat Belt. At the close of the month cutting was in progress as far north as southeastern Nebraska, and in the east was begun to southern Ohio.

While showers about the middle of June were beneficial for spring wheat, moisture was generally insufficient for that crop and poor to only fair progress was reported in most sections of the belt. Oats improved with the rains and cool weather over the northern half of the country, but it was too dry in some interior valley States, especially in the immediate Ohio Valley and parts of the Northwest. There were complaints of the crop heading on short straw in many sections of the country. Rice did well in the lower Mississippi Valley and West Gulf districts and in California was benefited by warm weather.

Corn.—The weather continued too cool, especially at night, for good growth of corn north of the Ohio and east of the Mississippi Rivers, and progress was slow and the crop late in that area. South of the Ohio River temperature conditions were more favorable and progress was mostly satisfactory, with moisture in the Southeast after the middle of the month very favorable. In the Southwest and generally between the Mississippi River and Rocky Mountains growth was mostly satisfactory, though it was rather too cool for best results in the northern half of the area, and moisture was deficient in a few sections. Locally in the upper Mississippi Valley there was too much rain for this crop about the middle of the month.

Cotton.—The weather was mostly favorable for the cotton crop, although it was rather too cool for good growth in the northeastern portion of the belt during much of the month, and too dry in the interior of the southeast during the first half. Following the rains in the Southeast the progress of the crop was very good and the germination of seeds that had lain dormant in the dry soil resulted in better stands, particularly in western North Carolina, central and northwestern South Carolina, and northern Georgia. In the western half of the belt it was rather too cool in the north, but progress of the crop in general was satisfactory, especially in much of Texas. There was considerable complaint of flea damage in many sections, but only local reports of weevil activity.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, June, 1926

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	77.6	−0.7	Madison	101	12	Valley Head	40	6	4.93	+0.67	Alaga	9.96	Winfield	1.35
Arizona	76.9	+0.9	Maricopa	120	27	Bright Angel Ranger Station.	26	18	0.14	−0.23	Waters Ranger Station.	1.17	31 stations	0.00
Arkansas	76.6	−0.5	Newport	104	12	Dutton	42	5	2.60	−1.42	Gravette	6.08	3 stations	0.79
California	71.6	+4.2	Greenland Ranch	124	27	Helm Creek	24	²13	0.07	−0.24	Ellery Lake	2.72	170 stations	0.00
Colorado	61.5	+0.6	Wray	105	29	Lake Moraine	15	13	1.28	−0.22	Burlington	4.15	3 stations	0.00
Florida	79.3	−0.6	8 stations	98	²9	Belle Glade	54	2	7.88	+1.29	Merritts Island	17.91	Pensacola	1.05
Georgia	77.9	−0.1	2 stations	102	²12	Blue Ridge	39	6	4.05	−0.36	Savannah	9.11	Hartwell	1.08
Idaho	64.0	+3.5	Chattin's Flat	113	26	Kirkham	18	8	0.72	−0.42	Potlatch	3.18	2 stations	0.00
Illinois	68.3	−3.6	Harrisburg	103	30	Waukegan	37	3	4.15	+0.25	Rockford	10.64	Cairo	0.60
Indiana	67.5	−4.1	Jeffersonville	99	12	Huntington	37	28	2.93	−0.90	Howe	8.10	Decker	0.99
Iowa	66.2	−3.1	Little Sioux	105	28	Decorah	32	3	4.52	−0.01	Lacona	12.09	New Hampton	1.05
Kansas	72.7	−0.4	Phillipsburg	107	²28	Oberlin	39	1	2.69	−1.26	Pittsburg	6.48	Atwood	0.42
Kentucky	70.9	−3.0	3 stations	98	²13	Junction City	42	6	3.42	−0.67	Munfordville	9.39	Louisville	0.86
Louisiana	79.9	−0.1	Dodson	101	²16	Lake Providence	45	6	3.46	−1.41	Delta Farms	7.91	Angola	0.91
Maryland–Delaware	67.6	−3.3	Ridgely, Md	98	30	Oakland, Md	35	²6	2.65	−1.28	Princess Anne, Md	4.89	2 stations	1.45
Michigan	59.5	−4.0	Monroe	96	29	Humboldt	25	19	3.61	+0.52	Frankfort	7.45	Eloise	1.70
Minnesota	60.9	−3.5	2 stations	101	28	Morris	28	6	3.34	−0.96	Hallock	6.41	Wheaton	0.82
Mississippi	78.7	−0.2	2 stations	101	²16	Batesville	47	6	3.30	−0.88	Agricultural College	9.44	Vicksburg	0.23
Missouri	70.9	−2.6	3 stations	101	²12	Lebanon	37	21	3.62	−1.05	Kidder	8.42	Fredericktown	0.34
Montana	60.6	+0.9	Biddle	108	27	2 stations	22	²8	2.10	−0.54	Augusta	5.55	Dillon	0.47
Nebraska	68.3	−1.0	Hayes Center	110	28	Gordon	33	1	2.75	−1.05	Tecumseh	8.31	Cambridge	0.86
Nevada	70.0	+5.1	Logandale	117	26	Rye Patch	27	14	0.26	−0.27	San Jacinto	1.23	Gerlach	0.00
New England	60.7	−3.5	Cavendish, Vt	94	25	Garfield, Vt	26	5	2.76	−0.78	Pittsburg, N. H	6.07	Storrs, Conn	0.79
New Jersey	64.9	−3.6	Cape May City	97	30	Layton	31	20	2.60	−1.10	Indian Mills	4.73	Atlantic City	1.29
New Mexico	67.8	−0.5	Jal	105	17	Tres Piedras	24	12	1.10	−0.34	San Jon	6.44	3 stations	0.00
New York	60.8	−4.1	3 stations	93	29	Allegany State Park	24	4	3.72	+0.04	High Market	7.70	West Point	1.36
North Carolina	72.5	−0.8	Rockingham	104	13	Mount Mitchell	32	6	3.89	−1.08	Newbern	8.62	Morgantown	0.80
North Dakota	60.7	−2.1	2 stations	104	²27	Pembina	22	18	2.62	−0.85	Mayville	5.66	Edgeley	0.66
Ohio	65.9	−3.6	Clarington	97	14	Canfield	32	4	3.11	−0.78	Middleport	6.07	2 stations	0.96
Oklahoma	76.8	+0.4	Mangum	110	16	2 stations	44	22	4.07	+0.18	Cleveland	13.21	Altus	0.83
Oregon	65.2	+4.1	2 stations	109	²6	Fremont	20	²15	0.36	−0.86	Headworks	2.02	13 stations	0.00
Pennsylvania	64.1	−4.1	4 stations	94	²13	West Bingham	23	4	3.63	−0.47	Cloe	6.56	Pittsburgh	1.20
South Carolina	77.2	−0.4	Blackville	103	²9	Walhalla	46	6	4.41	−0.38	Garnette	10.72	Catawba	0.90
South Dakota	65.5	−0.6	Pukwana	108	29	Camp Crook	32	1	3.02	−0.43	Harveys Ranch	11.55	Britton	0.42
Tennessee	73.2	−1.6	2 stations	99	²12	2 stations	39	6	4.64	+0.49	Lewisburg	9.23	Memphis	1.44
Texas	79.8	−0.3	Encinal	110	²14	Clint	48	17	3.09	−0.18	Liberty	9.32	Clint	0.02
Utah	67.6	+3.0	St. George	111	27	Great Basin Experiment Station, Alpine.	22	16	0.24	−0.35	Delle	1.02	19 stations	0.00
Virginia	69.7	−2.4	6 stations	99	²12	Burkes Garden	30	6	2.13	−2.24	Runnymede	4.96	Lexington	0.86
Washington	63.9	+3.2	4 stations	108	25	4 stations	28	1	0.73	−0.62	Spruce	8.40	3 stations	T.
West Virginia	65.9	−3.1	2 stations	95	²28	Morgantown	31	7	3.85	−0.96	Bayard	9.18	White Sulphur Springs.	0.90
Wisconsin	60.6	−3.9	Grantsburg	95	28	2 stations	28	²3	4.06	+0.01	Sturgeon Bay	7.45	2 stations	1.74
Wyoming	59.9	+0.7	3 stations	103	27	Dome Lake	19	21	1.63	+0.06	New Castle	6.15	Dubois	0.01
Alaska (May)	42.2	+2.2	Talkeetna	74	11	Wales	8	6	3.55	+1.03	Latouche	17.28	2 stations	0.05
Hawaii	74.3	+0.9	3 stations	91	²2	Waimea	50	16	4.93	+0.32	Eke	18.50	Puu Kea	0.00
Porto Rico	78.9	+0.6	Manati	99	16	3 stations	56	²3	4.36	−2.15	Mayaguez	14.75	Mona Island	0.40

[1] For description of tables and charts, see Review. ² Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, June, 1926*

District and station	Barometer above sea level (Ft.)	Thermometer above ground (Ft.)	Anemometer above ground (Ft.)	Station, reduced to mean of 24 hours (In.)	Sea level, reduced to mean of 24 hours (In.)	Departure from normal (In.)	Mean (+max.+min.)÷2 (°F)	Departure from normal (°F)	Maximum (°F)	Date	Mean maximum (°F)	Minimum (°F)	Date	Mean minimum (°F)	Greatest daily range (°F)	Mean wet thermometer (°F)	Mean temp. of dew point (°F)	Mean relative humidity (%)	Total (In.)	Departure from normal (In.)	Days with 0.01 or more	Total movement (Miles)	Prevailing direction	Max. vel. mi/hr	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Avg. cloudiness, tenths (0-10)	Total snowfall (In.)	Snow, sleet, ice on ground (In.)
New England							60.3	-3.2										73	2.38	-0.7										5.2		
Eastport	76	67	85	29.78	29.86	-.07	53.6	-1.5	77	17	63	40	6	44	31	51	49	85	2.77	-0.5	13	7,130	s.	34	se.	7	2	15	13	7.3	0.0	0.0
Greenville, Me.	1,070	6		28.72	29.87		56.6		81	25	68	34	6	46	40				3.00		14	5,037	nw.	38	ne.	15	19	4	7	4.1	0.0	0.0
Portland, Me.	103	82	117	29.78	29.90	-.05	59.3	-3.2	86	30	68	45	6	50	24	53	48	67	1.86	-1.5	9	6,591	sw.	26		19	7	11	12		0.0	0.0
Concord	289	70	79	29.58	29.89	-.07	61.0	-1.9	87	29	72	36	17	50	38				2.53	-0.8	12	4,277	ne.	38	se.	15	19	4	7	4.1	0.0	0.0
Burlington	403	11	48	29.44	29.87	-.09	59.6	-6.1	83	29	69	39	5	50	31				4.29	+1.0	12	7,611	sw.	25	sw.	26	16	7	7	4.1	0.0	0.0
Northfield	876	12	60	28.95	29.89	-.07	56.5	-4.8	82	29	60	32	5	44	28	52	47	69	4.55	+1.3	12	5,690	s.	46	s.	21	3	16	11	6.3	0.0	0.0
Boston	125	115	188	29.77	29.90	-.06	64.3	-2.2	88	30	73	46	4	56	27	56	50	62	1.33	-1.7	8	7,124	sw.	29	n.	15	10	13	7	5.3	0.0	0.0
Nantucket	12	14	90	29.90	29.91	-.07	59.1	-1.1	75	27	66	46	4	53	16	55	53	84	2.53	+0.1	8	11,295	sw.	54	ne.	15	10	9	11	6.1	0.0	0.0
Block Island	26	11	46	29.88	29.91	-.06	59.3	-2.5	77	30	65	47	4	54	17	55	53	82	1.58	-1.3	9	10,850	sw.	50	n.	15	10	9	9	4.6	0.0	0.0
Providence	160	215	251	29.75	29.92	-.05	63.7	-5.3	87	30	72	42	17	54	28	56	50	65	1.52	-1.6	7	8,683	nw.	42	nw.	10	15	6	9	4.6	0.0	0.0
Hartford	159	122		29.74	29.91	-.06	63.7	-3.4	86	30	73	42	17	54	28				1.22	-1.9	9		s.				16	7	7	4.3	0.0	0.0
New Haven	106	74	153	29.81	29.92	-.05	63.6	-3.0	87	30	72	43	4	55	23	57	52	69	1.97	-1.2	11	6,628	sw.	34	sw.	8	15					
Middle Atlantic States							67.1	-3.1										70	2.31	-1.4										5.8		
Albany	97	102	115	29.79	29.89	-.08	63.7	-4.3	89	29	73	45	4	54	27	57	53	71	2.77	-1.0	11	5,561	s.	34	s.	22	13	10	7	4.8	0.0	0.0
Binghamton	871	10	84	28.99	29.92	-.05	61.6	-4.0	87	29	73	37	20	51	33			71	2.83	-0.8	15	4,397	w.	27	sw.	8	7	11	12	6.2	0.0	0.0
New York	314	414	454	29.59	29.92	-.06	64.8	-4.0	84	30	72	48	4	57	28	57	52	67	2.47	-1.4	12	10,672	nw.	78	nw.	2	6	14	10	6.3	0.0	0.0
Harrisburg	374	94	104	29.54	29.93	-.06	66.8	-3.5	89	29	76	48	4	58	28	57	52	63	2.14	-1.4	10	4,849	sw.	33	sw.	7	6	12	12	6.2	0.0	0.0
Philadelphia	114	123	190	29.81	29.94	-.04	68.0	-3.4	90	14	77	52	17	59	26	61	56	70	2.81	-0.5	12	5,994	sw.	27	sw.	1	7	10	13	6.0	0.0	0.0
Reading	325	81	98	29.58	29.92		66.5		90	14	76	46	4	57	29	60	55	70	3.67	0.0	12	2,778	se.	27	sw.	13	8	13	10	4.9	0.0	0.0
Scranton	805	111	119	29.08	29.92	-.06	62.5	-5.3	85	29	73	40	4	52	33	56	50	66	2.65	-0.9	12	4,738	nw.	35	sw.	3	8	13	10	4.9	0.0	0.0
Atlantic City	52	37	172	29.88	29.93	-.05	64.9	-1.7	91	30	76	51	5	59	32	60	56	76	1.29	-1.7	11	11,064	s.	40	ne.	15	10	10	10	5.0	0.0	0.0
Cape May	17	13	49				68.6	+0.9	97	30	76	51	17	61	29				2.00	-1.0	9		s.				14	11	5		0.0	0.0
Sandy Hook	22	10	55	29.90	29.92		64.6		85	30	71	51	4	58	25	58	54	73	1.85		14	9,311	sw.	55	nw.	2		15	11	5.6	0.0	0.0
Trenton	190	159	183	29.72	29.92		65.6		90	14	76	47	17	56	28	59	55	71	2.46	-1.4	13	7,021	sw.	46	nw.	8	7	13	10	5.6	0.0	0.0
Baltimore	123	100	113	29.80	29.92	-.07	69.7	-3.0	92	30	78	49	5	61	30	61	56	64	2.46	-1.4	10	4,048	sw.	22	sw.	7	9	12		6.0	0.0	0.0
Washington	112	62	85	29.81	29.93	-.07	69.1	-3.1	91	14	79	48	5	59	31	61	56	66	1.66	-2.5	11	4,014	nw.	28	nw.	7	5	11	14	6.5	0.0	0.0
Cape Henry	18	8	54	29.91	29.93		71.8		97	14	79	55	7	64	31	65	62	77	2.24	-2.2	10	8,713	n.	44	n.	7	10	11	9	5.5	0.0	0.0
Lynchburg	681	153	188	29.21	29.94	-.05	72.6	-1.8	95	14	81	55	6	64	30	62	57	65	1.13	-2.8	10	4,963	w.	37	w.	12	10	12	8	5.7	0.0	0.0
Norfolk	91	170	205	29.85	29.95	-.05	72.6	-1.8	95	14	81	55	6	64	30	64	61	73	2.69	-1.6	12	8,646	nw.	51	nw.	12	8	10	12	6.1	0.0	0.0
Richmond	144	11	52	29.80	29.94	-.07	71.4	-2.7	99	14	82	52	5	61	34	63	59	55	1.74	-2.4	11	5,119	ne.	36	nw.	7	14	7	9	4.9	0.0	0.0
Wytheville	2,304	49	55	27.63	29.95	-.06	65.2	-3.5	87	30	76	42	6	55	36	59	55	75	1.74	-2.4	11	4,229	w.	34	sw.	7	7	12	11	6.1	0.0	0.0
South Atlantic States							76.0	-0.5										75	5.38	+0.5										5.5		
Asheville	2,253	70	84	27.68	29.96	-.05	68.0	-0.7	87	8	78	43	6	58	31	61	57	74	1.85	-2.4	13	4,690	n.	40	nw.	8	12	12	6	4.9	0.0	0.0
Charlotte	779	55	62	29.13	29.94	-.07	75.4	-0.1	98	12	86	52	6	64	33	65	59	64	3.29	-1.2	8	3,076	ne.	22	n.	8	5	18	7	5.9	0.0	0.0
Hatteras	11	11	50	29.93	29.94	-.07	73.2	-2.4	87	14	79	58	6	68	17	70	68	87	5.25	+0.9	17	9,640	sw.	35	sw.	7	13	7	10	5.9	0.0	0.0
Raleigh	376	103	110	29.51	29.94	-.07	76.3	-2.1	96	12	84	52	5	63	34	64	60	68	4.86	+0.1	14	5,493	nw.	33	nw.	23	9	11	10	5.7	0.0	0.0
Wilmington	78	81	91	29.87	29.95	-.06	76.0	-0.8	96	13	84	56	6	68	24	70	68	82	4.60	-1.0	10	5,665	sw.	25	sw.	7	10	10	10	5.5	0.0	0.0
Charleston	48	11	92	29.91	29.96	-.07	78.6	-0.3	96	13	86	60	6	72	19	72	70	82	5.65	+0.3	10	6,649	sw.	29	e.	17	10	12	8	5.6	0.0	0.0
Columbia, S. C.	351	41	57	29.58	29.94	-.07	78.0	-0.1	99	12	88	55	6	66	33	68	64	70	2.47	-1.7	13	4,907	sw.	27	sw.	15	6	17	7	5.1	0.0	0.0
Due West	711	10	55	29.22	29.98		76.2		99	12	87	55	6	65	31				2.47		14	6,229	sw.	40	nw.	23	3	21	6	5.6	0.0	0.0
Greenville, S. C.	1,039	139	146	28.87	29.94		75.3	+1.2	94	13	85	54	6	65	27	64	58	61	1.86		11	6,254	ne.	35	w.	7	8	15	7	5.2	0.0	0.0
Augusta	182	62	77	29.76	29.94	-.07	79.2	+0.5	100	11	90	57	6	69	28	71	68	74	7.41	+2.9	12	3,641	s.	26	w.	14	6	16	8	5.4	0.0	0.0
Savannah	65	150	194	29.89	29.96	-.05	78.9	-0.1	94	8	89	61	6	70	27	71	69	81	9.33	+3.8	13	7,144	sw.	33	sw.	27	11	9	10	5.4	0.0	0.0
Jacksonville	43	209	245	29.93	29.98	-.03	79.0	-0.9	93	14	87	63	6	71	22	71	69	80	9.33	+3.8	17	6,944	sw.	50	sw.	37	3	13	14	6.6	0.0	0.0
Florida Peninsula							81.2	+0.4										78	4.86	-2.0										5.9		
Key West	22	10	64	29.96	29.98	-.01	82.4	+0.5	90	23	88	72	10	77	15	76	74	78	3.37	-0.9	12	5,614	se.	27	se.	5	10	10	10	5.8	0.0	0.0
Miami	25	71	79	29.98	30.01		81.0	+0.6	90	22	86	70	6	76	18	75	72	76	3.24	-3.9	11	3,830	se.	23	se.	9	3	10	17	7.3	0.0	0.0
Tampa	35	79	87	29.94	29.94	-.03	80.2	0.0	92	8	88	67	6	73	25	73	71	80	7.07	-1.3	18	3,841	e.	23	s.	25	7	13	10	5.8	0.0	0.0
Titusville	44	5			29.93	29.98		80.1		98	24	90	61	7	70	29				11.03		17		sw.			9	15	6	5.1	0.0	0.0
East Gulf States							78.2	-0.3										73	4.20	-0.4										5.0		
Atlanta	1,173	190	216	28.76	29.97	-.04	75.3	-0.7	94	11	84	59	6	67	29	66	62	68	4.21	+0.3	11	6,357	w.	40	nw.	12	9	7	14	6.0	0.0	0.0
Macon	370	78	87	29.57	29.96	-.05	77.7	-1.2	96	12	88	60	6	67	29	66	62	68	6.93	+3.4	12	3,605	sw.	29	se.	16	10	12	8	5.1	0.0	0.0
Thomasville	273	49	58	29.68	29.97	-.03	78.7	-0.8	94	10	88	62	6	69	27	71	68	76	3.52	-1.2	13	2,730	sw.	24	e.	13	12	14		6.6	0.0	0.0
Apalachicola	36	42	49	29.93	29.97		78.3		89	29	86	65	6	72	20	71	70	79	9.66		15	4,467	sw.	29	n.	19	10	14	6	4.7	0.0	0.0
Pensacola	56	149	185	29.90	29.96	-.03	78.4	-0.9	90	19	84	62	6	73	19	73	71	78	1.05	-3.8	7	7,964	s.	36	nw.	19	6	14	10	5.5	0.0	0.0
Anniston	741	9	57	29.21	29.99	-.01	75.4	+0.4	95	11	87	50	6	64	33				4.46	+0.6	12	2,665	w.	20	sw.	3	13	12	5	4.1	0.0	0.0
Birmingham	700	11	48	29.23	29.98	-.01	77.0	-0.9	94	11	87	54	6	64	33	68	65	77	5.51	+1.6	11	3,485	s.	38	s.	3	13	13	4	4.1	0.0	0.0
Mobile	57	125	161	29.90	29.96	-.03	79.8	-0.5	94	11	88	60	6	71	24	72	70	77	5.05	-0.9	14	5,519	sw.	34	n.	11	7	20	3	4.8	0.0	0.0
Montgomery	223	100	112	29.73	29.97	-.03	79.2	-0.4	98	11	89	59	6	70	26	70	66	73	4.10	-0.1	14	4,176	sw.	29	n.	9	10	14	6	5.0	0.0	0.0
Corinth	469	6					77.1		98	17	89	51	6	65	33				2.12		9		s.				7	21	2		0.0	0.0
Meridian	375	87	95	29.57	29.95		77.9	-0.2	94	11	88	56	6	68	27	70	67	73	7.44	+2.8	9	3,334	sw.	27	w.	17	13	15	2	4.2	0.0	0.0
Vicksburg	247	65	73	29.70	29.97	.00	79.4	-0.4	94	17	90	61	6	70	25	70	66	66	0.23	-4.3	3	3,957	s.	20	nw.	15	12	10	8	4.5	0.0	0.0
New Orleans	53	76	84	29.91	29.96	-.02	81.8	+1.2	94	17	89	67	6	74	19	73	70	72	3.70	-2.5	13	3,571	sw.	21	e.	9	9	15		5.0	0.0	0.0
West Gulf States							79.3	-0.3										72	2.89	-0.8										4.2		
Shreveport	249	77	93	29.69	29.95	-.01	80.1	-0.6	94	16	90	60	6	70	28	71	67	71	2.97	-0.6	9	4,361	s.	30	nw.	21	15	12	3	3.9	0.0	0.0
Bentonville	1,303	11	44				71.8	-2.3	92	13	82	47	5	61	30				4.87		9	3,229	s.	19	s.	16	17	9	4	3.9	0.0	0.0
Fort Smith	457	79	94	29.45	29.92	-.02	76.9	-0.6	95	16	87	57	5	67	33	69	65	67	4.13	+0.1	7	4,581	e.	30	nw.	15	16	9	4	4.0	0.0	0.0
Little Rock	357	136	144	29.57	29.94	-.02	77.9	+0.4	95	12	88	57	5	67	33	69	67	61	1.47	-2.6	5	5,455	s.	38	nw.	15	15	9		4.3	0.0	0.0
Brownsville	57	53	61	29.83	29.89		81.7	-0.7	92	30	89	68	6	74	21	75	74	82	3.35		9	4,867	s.	20	n.	5	14	11	5	4.6	0.0	0.0
Corpus Christi	20	11	73	29.90	29.92	+.01	81.3	+0.3	91	14	87	70	22	76	18	76	74	82	0.94	-1.8	8	8,563	se.	32	se.	15	13	12	5	4.6	0.0	0.0
Dallas	512	109	117	29.40	29.93		80.0		97	14	90	64	6	70	29				2.46		8	5,591	s.	30	ne.	21	18	9	3	3.2	0.0	0.0
Fort Worth	670	106	114	29.21	29.91	-.01	79.7	-0.2	98	15	90	59	5	69	33	68	63	65	3.32	+0.2	6	6,448	s.	29	s.	13	14	12	4	3.5	0.0	0.0
Galveston	54	106	114	29.91	29.97	+.02	80.8	+0.1	88	20	85	69	4	76	16	74	72	77	1.53	-3.2	8	6,941	s.	32	nw.	22	15	14	1	3.7	0.0	0.0
Groesbeck	461	11	56	29.46	29.93		78.8		94	17	88	58	6	69	26				5.04		9	6,403	s.	43	ne.	17	12	13		4.5	0.0	0.0
Houston	138	292	314	29.82	29.96		80.4	-1.0	95	21	89	64	6	72	30				8.95		12	7,392	s.	39	n.	26	10	18	2	4.5	0.0	0.0
Palestine	510	64	72	29.42	29.94	.00	78.6	-0.4	94	17	88	62	6	69	30	71	68	75	7.27	+3.3	13	4,563	s.	39	se.	4	11	16	3	4.2	0.0	0.0
Port Arthur	34	58	66	29.91	29.95		81.2		93	21	88	63	6	74	21				2.32		7	5,463	s.	30	ne.	4	15	12	3	3.6	0.0	0.0
San Antonio	693	119	132	29.20	29.91	+.01	81.6	+0.6	98	21	92	65	6	71	28	72	69	69	3.57	+0.5	6	4,921	s.	39	ne.	27	6	19	5	4.0	0.0	0.0
Taylor	583	55	63	29.36	29.97	+.05	80.7	+0.7	96	17	91	57	6	71	32				2.67	-0.8	4	6,081	s.	37	s.	14	10	17	3	4.4	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, June, 1926*—Continued

Districts and stations	Elevation of instruments			Pressure			Temperature of the air										Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity								
																								Miles per hour	Direction	Date						
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.* 70.2	°*F.* −2.5	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	% 64	*In.* 2.56	*In.* −1.6		*Miles*								0–10 5.1	*In.*	*In.*
Chattanooga	762	189	213	29.15	29.94	−.06	75.2	−0.2	94	12	85	53	6	66	27	66	61	67	5.60	+1.3	13	4,653	sw.	29	w.	8	8	15	7	5.2	0.0	0.0
Knoxville	995	102	111	28.91	29.94	−.06	73.2	−0.8	96	12	84	50	6	63	29	65	61	70	5.07	+0.9	13	4,086	ne.	27	s.	7	7	16	7	5.4	0.0	0.0
Memphis	399	76	97	29.53	29.94	−.03	77.2	−0.4	94	10	86	56	5	68	26	67	62	62	1.44	−2.9	8	5,112	sw.	32	n.	21	15	7	8	3.9	0.0	0.0
Nashville	546	168	191	29.40	29.97	−.02	73.6	−2.0	93	13	83	53	6	64	30	65	61	67	2.17	−2.2	10	5,409	w.	42	nw.	17	9	16	5	4.7	0.0	0.0
Lexington	989	193	230	28.91	29.96	−.04	69.4	−2.8	89	17	78	51	5	61	27				2.78	−1.2	14	8,863	sw.	57	nw.	17	15	11	4	3.9	0.0	0.0
Louisville	525	188	284	29.38	29.96	−.02	71.4	−3.3	90	11	81	52	27	62	29	61	55	60	0.86	−3.4	7	7,529	s.	38	w.	12	9	17	4	4.8	0.0	0.0
Evansville	431	139	175	29.51	29.97	−.01	73.2	−1.9	98	30	84	53	5	63	31	62	54	55	1.09	−3.1	6	7,123	w.	37	w.	7	7	20	3	5.1	0.0	0.0
Indianapolis	822	194	230	29.06	29.94	−.03	68.2	−3.4	91	13	78	48	27	59	29	58	51	57	1.28	−3.0	9	8,069	w.	46	s.	21	11	5	14	5.2	0.0	0.0
Royal Center	736	11	55	29.12	29.91		64.0		92	29	75	40	27	53	34				2.13			10	7,268	w.	44	w.	7	9	10	11	5.2	0.0	0.0
Terre Haute	575	96	129	29.32	29.93		69.1		92	29	79	50	27	59	30	50	53	59	1.36			12	6,699	nw.	33	sw.	6	7	18	5	5.2	0.0	0.0
Cincinnati	627	11	51	29.27	29.94	−.05	68.8	−2.4	92	30	79	49	27	58	31		58	68	2.61	−1.4	9	4,867	sw.	38	nw.	21	11	13	6	4.6	0.0	0.0
Columbus	822	179	222	29.07	29.94	−.05	67.4	−1.5	89	29	77	48	3	58	29	59	54	65	0.96	−2.5	12	6,972	nw.	39	nw.	7	8	15	7	5.5	0.0	0.0
Dayton	899	137	173	28.98	29.91	−.05	67.5	−1.9	89	14	79	45	6	58	29	59	52	61	2.09	−1.9	12	6,514	sw.	46	w.	14	9	17	4	4.7	0.0	0.0
Elkins	1,947	59	67	27.94	29.95	−.05	62.6	−4.3	85	14	73	42	6	52	35	57	54	75	3.86	−1.2	13	3,620	w.	26	w.	7	6	13	11	6.3	0.0	0.0
Parkersburg	637	77	82	29.31	29.96	−.04	68.5	−2.9	89	14	79	45	6	58	33	59	54	66	4.85	+0.2	15	4,002	sw.	36	nw.	14	10	10	10	5.4	0.0	0.0
Pittsburgh	842	353	410	29.04	29.93	−.06	66.4	−4.3	88	14	76	47	4	57	29	57	52	62	1.20	−2.7	11	8,058	sw.	48	sw.	21	9	10	11	5.8	0.0	0.0
Lower Lake Region							62.3	−4.5										67	3.21	−0.3										4.6		
Buffalo	767	247	280	29.07	29.90	−.07	59.0	−5.4	79	21	66	40	3	52	25	54	51	78	2.80	−0.3	11	12,113	sw.	54	nw.	2	8	17	5	5.2	0.0	0.0
Canton	448	10	61	29.40	29.87		59.8	−6.0	80	29	70	39	4	50	32				4.15	+0.7	13	7,879	sw.	48	w.	2	15	10	5	3.9	0.0	0.0
Oswego	335	76	91		29.88	−.09	57.6	−7.2	80	29	66	40	3	49	29			70	2.60	−0.8	11		s.	26	s.	21	10	11	9		0.0	0.0
Rochester	523	86	102	29.33	29.90	−.07	61.5	−5.4	87	29	71	41	3	52	30	54	48	62	3.18	0.0	13	6,266	w.	41	w.	2	9	13	8	5.2	0.0	0.0
Syracuse	597	97	113	29.27	29.91	−.06	61.3	−5.6	86	29	70	41	3	52	30				3.12	−1.8	13	6,009	s.	37	s.	21	10	12	8	5.0	0.0	0.0
Erie	714	130	166	29.14	29.90	−.08	63.0	−3.2	86	29	71	43	4	55	27	58	54	74	5.32	+1.6	11	10,126	sw.	46	sw.	2	13	14	3	4.3	0.0	0.0
Cleveland	762	190	201	29.10	29.91	−.07	64.3	−2.8	89	29	72	44	4	56	29	57	51	65	2.58	−1.1	14	8,749	s.	42	w.	7	11	12	7	4.7	0.0	0.0
Sandusky	629	62	70	29.23	29.91	−.07	65.2	−3.6	92	29	74	46	3	57	30				1.63	−2.2	12	6,256	nw.	37	nw.	2	10	11	9	5.0	0.0	0.0
Toledo	628	208	243	29.24	29.91	−.06	65.0	−3.7	91	29	74	42	3	56	27	57	50	61	3.87	+0.5	11	9,737	sw.	51	sw.	21	16	12	2	3.6	0.0	0.0
Fort Wayne	856	113	124	29.00	29.91		65.2	−3.3	92	29	76	45	3	55	31	57	52	65	1.88		8	6,326	sw.	40	nw.	29	12	14	4	4.7	0.0	0.0
Detroit	730	218	258	29.12	29.91	−.06	63.4	−4.0	89	29	73	39	3	54	31	55	49	61	2.81	−1.1	11	7,467	nw.	37	w.	1	12	14	4	4.8	0.0	0.0
Upper Lake Region							58.9	−4.1										70	3.49	+0.1										4.9		
Alpena	609	13	92	29.20	29.86	−.10	56.9	−3.5	83	28	67	34	3	47	30	51	46	68	2.24	−1.3	13	9,067	nw.	40	s.	21	14	9	7	5.2	0.0	0.0
Escanaba	612	54	60	29.20	29.86	−.08	57.6	−3.1	88	28	67	36	3	48	31	51	47	72	3.73	+0.4	14	7,348	s.	28	n.	18	12	10	8	4.7	0.0	0.0
Grand Haven	632	54	89	29.21	29.89	−.07	58.1	−5.6	80	13	66	40	4	50	26	53	49	72	2.15	−0.4	10	7,816	w.	37	s.	6	12	12	6	4.3	0.0	0.0
Grand Rapids	707	70	87	29.14	29.91	−.06	62.2	−5.6	84	29	72	38	3	52	28	55	49	63	2.66	+0.1	14	4,777	w.	28	w.	2	10	9	11	5.3	0.0	0.0
Houghton	668	62	99	29.12	29.84	−.10	55.8	−4.2	86	28	65	37	2	46	33				3.37	−0.1	12	8,148	w.	53	w.	22	9	8	13	5.8	0.0	0.0
Lansing	878	11	62	28.96	29.89		61.8	−4.6	88	29	74	35	3	50	31	49	51	69	2.90	−0.5	7	4,236	nw.	26	se.	6	12	14	4	4.1	0.0	0.0
Ludington	637	60	66	29.19	29.89		55.4		77	29	63	40	4	48	24	52	48	75	4.25		13	7,457	s.	48	s.	21	13	10	7	4.1	0.0	0.0
Marquette	734	77	111	29.06	29.87	−.07	55.7	−3.2	91	28	64	36	2	48	29	50	45	69	2.62	−0.9	13	7,515	w.	40	sw.	28	7	10	13	6.2	0.0	0.0
Port Huron	638	70	120	29.20	29.88	−.09	60.2	−4.0	90	29	70	36	3	51	31	54	50	70	3.51	+0.3	10	7,988	ne.	46	nw.	1	10	15	5	4.5	0.0	0.0
Saginaw	641			29.18	29.88		61.0	−5.9	90	29	73	36	3	49	36				2.58			10		w.				10	9	11			0.0	0.0
Sault Sainte Marie	614	11	52	29.17	29.86	−.10	52.6	−6.0	76	11	62	35	4	43	35	48	44	75	4.42	+1.6	14	6,151	nw.	31	nw.	2	11	8	11	5.5	0.0	0.0
Chicago	673	7	131	29.21	29.93	−.03	63.4	−3.9	84	29	72	47	5	55	25	56	50	66	7.62	+4.0	9	8,016	sw.	42	w.	7	14	9	7	4.3	0.0	0.0
Green Bay	617	109	141	29.21	29.86	−.09	60.6	−4.3	85	29	70	39	3	51	29	54	50	52	4.50	+1.0	12	8,638	s.	45	n.	21	13	9	8	5.1	0.0	0.0
Milwaukee	681	125	139	29.26	29.89	−.06	60.6	−3.3	87	29	69	41	2	52	24	54	48	66	1.91	−1.9	9	7,278	w.	49	s.	21	11	13	6	4.9	0.0	0.0
Duluth	1,133	5	47	28.67	29.88	−.04	56.7	−0.5	92	28	67	39	19	46	32	50	44	68	3.93	−0.6	14	10,004	ne.	48	ne.	21	10	10	10	5.6	0.0	0.0
North Dakota							60.6	−2.7										61	1.87	−1.8										5.2		
Moorhead	940	50	58	28.88	29.89	−.01	60.2	−4.2	91	27	72	38	2	48	41	54	48	65	2.09	−2.0	11	6,814	n.	36	nw.	21	5	11	14	6.3	0.0	0.0
Bismarck	1,674	8	57	28.18	29.94	+.07	63.2	−0.7	100	27	75	34	2	51	44	53	45	57	1.81	−1.7	11	7,858	nw.	48	n.	20	15	6	9	4.4	0.0	0.0
Devils Lake	1,478	11	44	28.35	29.91	+.03	58.6	−4.0	97	27	71	36	2	46	47	51	45	62	1.74	−1.8	12	7,785	nw.	56	nw.	5	12	11	7	4.7	0.0	0.0
Ellendale	1,457	10	56	28.37	29.92		62.6		100	28	76	35	2	50	47				0.77		9	11,059	nw.	62	nw.	21	6	13	11	5.9	0.0	0.0
Grand Forks	833	12	67				59.7		89	10	72	37	18	48	36	54			4.30		7		nw.	42	nw.	21	14	10	6	5.1	0.0	0.0
Williston	1,878	41	48	27.96	29.92	+.06	60.6	−2.1	94	27	72	39	2	49	37	52	45	61	1.83	−1.7	9	6,468	n.	32	n.	20	12	10	8	4.8	0.0	0.0
Upper Mississippi Valley							67.0	−3.4										63	3.79	−0.6										5.0		
Minneapolis	918	102	208	28.88	29.85		64.1	−3.4	94	28	74	42	2	54	30				3.76	−0.2	10	7,915	nw.	48	nw.	21	6	16	8	5.5	0.0	0.0
St. Paul	837	236	261	28.98	29.88	−.04	63.7	−3.4	93	28	74	42	2	54	31				3.65	−0.8	9	9,900	nw.	50	sw.	21	11	16	3	4.7	0.0	0.0
La Crosse	714	11	48	29.12	29.88	−.05	63.3	−5.0	90	28	74	40	3	52	36				1.74	−2.7	9	3,383	se.	21	sw.	21	8	15	7	5.5	0.0	0.0
Madison	974	70	78	28.87	29.90	−.04	63.0	−4.2	83	12	72	45	3	54	26	56	50	65	2.16	−1.9	10	6,288	nw.	37	ne.	14	8	13	9	5.5	0.0	0.0
Wausau	1,247	4		28.56	29.87		60.2		85	12	70	38	3	50	30				3.89			15		w.				10	8	12	5	7	0.0	0.0
Charles City	1,015	10	49	28.85	29.91	.00	63.2	−3.3	94	28	75	42	3	52	37	56	50	62	1.28	−3.8	11	4,595	se.	26	se.	20	15	9	6	3.9	0.0	0.0
Davenport	606	71	79	29.26	29.92	−.02	67.4	−3.1	92	11	78	48	26	57	29	50	52	62	5.13	+1.0	9	5,488	w.	33	w.	1	11	14	5	4.6	0.0	0.0
Des Moines	861	84	97	29.01	29.90	−.02	67.9	−2.7	92	28	79	47	26	57	32	59	51	58	6.11	+1.2	8	5,144	w.	32	sw.	11	11	10	9	5.3	0.0	0.0
Dubuque	700	81	96	29.15	29.89	−.04	64.4	−5.0	86	12	74	45	3	55	32	57	50	61	3.76	−0.8	8	4,835	nw.	38	nw.	11	9	12	9	5.4	0.0	0.0
Keokuk	614	64	78	29.27	29.94	−.00	68.6	−3.9	94	11	78	50	26	59	29	60	54	63	7.57	+3.2	9	5,462	w.	34	nw.	7	9	14	7	5.1	0.0	0.0
Cairo	358	87	93	29.56	29.94	−.03	74.1	−2.2	94	12	84	55	5	65	28	64	58	62	0.60	−3.7	5	5,713	n.	28	w.	14	7	14	7	5.8	0.0	0.0
Peoria	609	11	45	29.28	29.94	−.01	67.2	−3.7	94	11	78	45	5	56	34	59	53	65	5.63	+1.3	12	4,150	nw.	28	w.	1	13	12	5	4.5	0.0	0.0
Springfield, Ill.	636	10	91	29.26	29.93	−.01	69.2	−3.0	94	29	79	51	20	59	29	60	54	62	5.01	+0.7	15	5,597	w.	28	w.	7	11	12	7	4.5	0.0	0.0
Hannibal	534	74	100	29.37	29.94	−.01	69.3	−3.2	94	29	80	51	27	59	33				4.93	+1.4	10	6,117	sw.	37	nw.	12	11	12	7	4.7	0.0	0.0
St. Louis	568	265	303	29.34	29.94	−.01	72.6	−2.2	93	29	82	54	4	63	27	61	55	58	1.72	−2.8	11	8,178	sw.	37	nw.	12	9	14	7	4.9	0.0	0.0
Missouri Valley							69.6	−1.2										59	2.57	−1.8										4.5		
Columbia, Mo.	784	11	84	29.11	29.93	−.02	70.0	−2.8	95	12	80	48	27	59	31				2.91	−1.5	13	5,061	w.	33	w.	16	9	15	6	4.9	0.0	0.0
Kansas City	963	161	181	28.91	29.93	+.01	72.2	−1.4	98	29	82	53	19	63	28	62	57	63	1.55	−3.1	11	7,298	s.	44	nw.	16	14	13	3	4.5	0.0	0.0
St. Joseph	967	11	49	28.90	29.91		72.0		98	29	83	51	19	61	31	62	56	63	5.44		11	5,517	sw.	50	nw.	13	16	8	6	4.7	0.0	0.0
Springfield, Mo.	1,324	98	104	28.60	29.93	+.03	69.8	−2.7	98	7	79	50	5	61	30	64	63	70	3.97	−1.2	12	6,258	s.	36	nw.	8	16	11	3	3.0	0.0	0.0
Iola	964	11	50	28.91	29.93	.00	72.1	−2.0	94	12	83	51	5	61	33				4.06	−1.4	12	4,246	s.	25	nw.	8	14	10	6	4.7	0.0	0.0
Topeka	987	92	107				72.3	−1.1	99	29	83	51	19	61	32				2.49	−2.3	9	6,529	sw.	42	e.	15	16	11	3	3.5	0.0	0.0
Drexel	1,299	10	54																													
Lincoln	1,189	11	84	28.66	29.90	.00	70.9	−0.5	100	28	83	47	19	59	38	60	53	58	2.58	−1.7	9	7,073	s.	46	w.	20	5	17	8	5.9	0.0	0.0
Omaha	1,105	115	122	28.75	29.90	−.01	70.6	−1.0	101	28	81	50	19	59	36	59	51	53	2.01	−3.0	10	5,420	nw.	34	nw.	6	15	10	5	4.4	0.0	0.0
Valentine	2,596	47	54	27.26	29.94	+.08	65.9	−1.0	102	28	78	44	4	54	40	54	49	58	2.18	−1.6	13	6,997	nw.	42	w.	21	11	13	6	4.7	0.0	0.0
Sioux City	1,135	94	164	28.72	29.91	+.01	68.6	−0.9	102	28	80	46	26	57	40	58	50	56	1.92	−2.0	8	8,532	s.	46	nw.	6	7	18	5	5.2	0.0	0.0
Huron	1,306	59	74	28.55	29.93	+.05	66.2	−0.3	103	28	78	42	2	54	40	56	48	55	2.17	−1.5	8	7,271	nw.	48	nw.	21	14	11	5	4.1	0.0	0.0
Pierre	1,572	70	75		29.91	+.04	67.7	−0.8	105	24	80	45	2	56	41			55	1.86	−1.2	9	7,515	nw.	48	nw.	21	12	10	8		0.0	0.0
Yankton	1,233	49	57	28.61	29.91	+.02	68.9	0.0	102	28	81	45	26	57	39				3.18	−1.1	6	5,736	w.	31	w.	6	8	18	4	5.0	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, June, 1926*—Continued

Districts and stations	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dewpoint	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Northern Slope							62.7	+1.2										57	2.25	0.0										5.1		
Billings	3,140	5	44	27.33	29.93	+.08	63.4		103	27	78	33	21	48	48			57	0.67	−0.6	8	4,894	nw.	32	w.	27	14	6	10		0.0	0.0
Havre	2,505	11	44	25.81	29.94	+.06	63.4	−1.4	93	26	77	40	1	50	40	52	44	57	2.23	−0.6	7	4,894	e.	32	w.	29	15	10	5	4.2	0.0	0.0
Helena	4,110	87	112	25.81	29.94	+.06	61.7	+2.5	92	26	74	39	21	50	38	49	39	50	1.85	−0.3	7	5,737	sw.	32	sw.	29	3	14	13	6.6	0.0	0.0
Kalispell	2,973	48	56	26.91	29.93	+.04	60.6	+2.9	95	26	74	36	10	47	37	48	38	54	1.20	−0.5	7	4,781	nw.	28	sw.	26	15	12	3	3.9	0.0	0.0
Miles City	2,371	48	55	27.44	29.96	+.11	66.0	+0.6	104	27	78	44	1	55	39	54	46	54	1.67	−1.1	7	4,637	ne.	36	nw.	11	13	7	10	4.9	0.0	0.0
Rapid City	3,259	50	58	26.60	29.96	+.11	64.2	0.0	98	27	75	44	17	53	36	55	48	60	3.37	−0.2	9	5,426	se.	36	nw.	20	7	12	11	5.6	0.0	0.0
Cheyenne	6,088	84	101	24.06	29.92	+.08	60.4	0.0	87	27	73	36	21	48	42	50	44	61	4.73	+3.2	10	6,917	s.	56	nw.	20	7	13	10	5.9	0.0	0.0
Lander	5,372	60	68	24.67	29.92	+.07	63.4	+2.9	94	27	78	37	21	48	40	53	46	61	0.23	−0.9	5	4,217	sw.	58	sw.	9	7	20	3	5.0	0.0	0.0
Sheridan	3,790	10	47	26.10	29.95		62.0		100	27	77	34	21	47	43	53	46	61	1.67		12	3,300	nw.	36	nw.	29	6	19	5	5.1	0.0	0.0
Yellowstone Park	6,241	11	48	23.08	29.96	+.10	55.6	+0.4	87	27	70	30	21	41	43	45	38	60	1.19	−0.4	15	4,952	s.	39	s.	18	5	17	8	5.7	T.	0.0
North Platte	2,821	11	51	27.07	29.95	+.09	68.0	+0.5	101	28	81	46	1	55	39	58	52	53	3.80	+0.6	14	4,598	nw.	29	nw.	20	15	9	6	4.3	0.0	0.0
Middle Slope							72.0	+0.1										58	2.32	−0.8										4.6		
Denver	5,292	106	113	24.77	29.93	+.00	66.0	+0.3	92	28	79	45	21	55	33	53	44	53	0.86	−0.6	8	5,123	s.	36	nw.	1	6	20	4	5.3	0.0	0.0
Pueblo	4,685	80	86	25.30	29.88	−.05	70.2	+1.2	96	28	86	45	22	55	42	54	45	50	0.83	−0.6	6	4,924	e.	36	sw.	10	10	19	1	4.4	0.0	0.0
Concordia	1,392	50	58	28.46	29.90	.00	72.4	−0.4	99	29	84	48	19	61	38	60	55	57	2.97	−2.0	10	5,575	s.	25	s.	20	5	16	9	5.8	0.0	0.0
Dodge City	2,509	11	51	27.37	29.92	+.05	72.8	+0.3	97	30	86	49	23	60	38	61	55	60	2.44	−0.9	8	6,658	sw.	36	ne.	16	17	10	3	3.3	0.0	0.0
Wichita	1,358	139	158	28.50	29.94	−.01	73.6	−0.8	99	16	84	52	19	63	32	64	58	63	3.03	−1.7	9	9,398	s.	47	s.	13	11	18	1	4.2	0.0	0.0
Broken Arrow	765	11	56	29.12	29.94		73.8		93	12	84	55	5	64	28				4.25		10	8,110	s.	48	nw.	14	4	17	9	5.4	0.0	0.0
Broken Arrow	652	4																														
Muskogee	1,214	10	47	28.66	29.90	−.01	76.2	+0.2	97	7	87	55	19	65	34	67	62	67	3.77	+0.7	8	7,142	s.	41	s.	15	16	9	5	4.1	0.0	0.0
Oklahoma City							77.5	−0.4										56	3.35	+0.8										3.8		
Southern Slope																																
Abilene	1,738	10	52	28.13	29.89	+.01	79.4	+0.2	100	14	91	56	5	68	34	67	62	62	5.78	+2.6	6	6,633	s.	52	ne.	14	11	13	6	4.8	0.0	0.0
Amarillo	3,676	10	49	26.27	29.91	+.06	73.1	+0.3	95	15	86	54	22	60	35	62	55	60	3.17	−0.2	10	7,168	s.	31	n.	21	20	8	2	3.0	0.0	0.0
Del Rio	944	64	71	28.91	29.87	+.02	83.2	−1.2	99	14	92	65	22	72	26				3.46	+1.0	6	7,257	se.	40	ne.	22	12	13	5	4.3	0.0	0.0
Roswell	3,566	75	85	26.33	29.85	+.05	75.4	−0.9	97	15	90	55	6	61	38	59	48	47	1.01	−0.8	2	5,381	s.	42	ne.	24	12	18	0	3.2	0.0	0.0
Southern Plateau							76.6	+2.4										34	0.18	−0.2										2.2		
El Paso	3,778	152	175	26.13	29.79	+.04	82.0	+2.4	102	24	95	62	5	69	33	59	41	29	0.11	−0.4	2	7,042	e.	41	w.	4	25	5	0	2.3	0.0	0.0
Santa Fe	7,013	38	53	23.32	29.82	+.01	66.4	+1.2	86	30	79	46	5	53	34	50	38	42	0.32	−0.7	6	4,543	se.	27	ne.	2	13	15	2	3.5	0.0	0.0
Flagstaff	6,907	10	59	23.42	29.85	+.07	60.8	+1.5	87	24	79	37	21	43	43	44		41	0.11		3	5,576	nw.	35	w.	25	16	14	0		0.0	0.0
Phoenix	1,108	10	82	28.63	29.75	+.01	87.0	+2.5	113	20	103	64	19	71	39	61	40	23	T.	−0.1	0	3,965	e.	29	ne.	5	22	6	2	2.1	0.0	0.0
Yuma	141	62	54	29.58	29.72	−.02	86.8	+2.1	114	29	104	62	16	69	40	65	50	35	T.	0.0	0	3,057	sw.	17	s.	7	27	3	0	1.0	0.0	0.0
Independence	3,957	5	25	25.92	29.86	+.08	77.0	+4.7	102	26	93	54	18	61	40	54			0.46	+0.4	3		nw.				13	16	7			0.0	0.0
Middle Plateau							70.5	+5.3										32	0.15	−0.3										3.4		
Reno	4,532	74	81	25.46	29.87	+.01	70.0	+9.0	99	25	86	41	20	53	43	50	35	35	0.10	−0.3	4	5,021	w.	39	w.	3	20	6	4	3.0	0.0	0.0
Tonopah	6,090	12	20				70.8		95	26	82	48	16	60	30	51	28	28	0.25		3		nw.				14	15	1	3.3		
Winnemucca	4,344	18	56	25.59	29.90	+.02	68.7	+5.9	102	26	87	37	16	50	48	51	38	40	0.30	−0.3	3	4,363	sw.	30	sw.	27	14	15	1	3.3	0.0	0.0
Modena	5,473	10	43	24.61	29.83	+.01	67.8	+4.5	98	27	86	40	16	50	47	48	30	30	0.06	−0.3	1	8,278	sw.	40	w.	29	16	13	1	3.0	0.0	0.0
Salt Lake City	4,360	163	203	25.59	29.87	+.02	72.0	+4.6	101	27	84	48	16	60	33	37	32	32	0.21	−0.6	4	5,009	nw.	35	w.	9	16	10	4	3.7	0.0	0.0
Grand Junction	4,602	60	68	25.34	29.85	+.02	73.9	+2.5	100	27	88	50	22	60	35	53	35	30	0.06	−0.3	4	4,866	se.	43	se.	27	14	14	2	3.8	0.0	0.0
Northern Plateau							68.1	+4.4										42	0.89	−0.2										3.9		
Baker	3,471	48	53	26.45	29.98	+.03	62.2	+3.6	96	25	78	36	11	47	44	50	41	51	0.50	−0.7	6	4,047	nw.	18	nw.	8	19	6	5	3.4	0.0	0.0
Boise	2,739	78	86	27.11	29.91	.00	70.2	+4.9	105	26	85	42	15	55	39	52	37	38	0.16	−0.7	1	3,518	w.	26	nw.	19	16	12	2	3.5	0.0	0.0
Lewiston	757	40	48	29.14	29.94	.00	70.8	+4.2	103	25	86	47	2	56	41	50		32	2.19	+1.2	5	2,643	e.	31	nw.	8	16	9	5	4.3	0.0	0.0
Pocatello	4,477	60	68	25.45	29.87	.00	68.4	+6.2	99	26	83	40	17	54	41	50	34	34	0.54	−0.4	4	5,376	se.	36	sw.	8	15	6		5.0	0.0	0.0
Spokane	1,929	101	110	27.94	29.95	+.01	65.5	+2.7	98	25	79	43	9	52	40	51	39	46	0.79	−0.5	4	4,143	s.	24	sw.	8	12	15	3	4.6	0.0	0.0
Walla Walla	991	57	65	28.89	29.94	−.02	71.5	+5.0	104	25	85	50	12	58	39	56	42	40	1.18	0.0	4	3,372	s.	15	w.	10	22	5	3	2.7	0.0	0.0
North Pacific Coast Region							62.1	+3.7										71	0.33	−1.5										4.8		
North Head	211	11	56	29.87	30.10	+.11	56.2	+1.4	71	24	60	−50	10	53	19	54	52	86	0.35	−1.4	9	10,637	nw.	42	n.	28	6	8	16	7.4	0.0	0.0
Port Angeles	29	8	53				57.2		80	24	66	43	3	49	30				0.11	−1.2	1	5,778	sw.	32	w.	8	8	15	7		0.0	0.0
Seattle	125	215	250	29.92	30.05	+.05	62.8	+3.8	88	24	72	46	11	54	31	54	48	63	0.40	−1.0	3	5,955	n.	32	sw.	1	12	7	11	4.9	0.0	0.0
Tacoma	194	172	201	29.86	30.06	+.03	63.0	+4.3	88	24	72	48	11	54	34				0.14	−1.5	2	6,367	n.	27	sw.	26	11	15	4	4.7	0.0	0.0
Tatoosh Island	86	9	53	29.99	30.09	+.07	55.4	+2.4	73	24	59	48	2	52	19	53	52	91	0.48	−3.7	10	6,636	sw.	42	nw.	9	1	14	4	4.3	0.0	0.0
Yakima	1,071	5					69.8		103	27	87	39	11	52	50			50	0.27				nw.				5	12	14	4		0.0	0.0
Medford	1,425	4					70.6		109	6	91	41	20	50	54	58	51	61	0.05		1		nw.				21	4	5			0.0	0.0
Portland, Oreg	153	68	106	29.88	30.04	.00	67.0	+4.6	99	24	78	48	11	56	35	59	54	66	0.35	−1.3	4	4,669	nw.	24	nw.	6	16	5	9	4.2	0.0	0.0
Roseburg	510	9	57	29.48	30.02	−.01	68.2	+5.7	101	24	84	−45	11	52	47	56	47	56	0.45	−0.6	1	2,933	n.	15	n.	8	23	7	0	1.7	0.0	0.0
Middle Pacific Coast Region							64.6	+2.2										65	T.	−0.4										3.6		
Eureka	62	73	89	29.98	30.05	.00	55.5	+1.2	63	19	59	47	9	52	12	52	50	85	T.	−1.1	0	4,661	nw.	23	nw.	13	6	17	7	6.0	0.0	0.0
Point Reyes	490	7	18	29.36	29.88		52.4	−0.4	60	5	56	47	4	49	11				0.00		0	19,755	nw.	62	nw.	13	12	5	13	6.0	0.0	0.0
Red Bluff	332	50	56	29.48	29.83	−.05	81.0	+6.2	109	6	97	55	15	65	40	62	48	37	0.00	−0.5	0	3,600	se.	19	nw.	20	25	4	1	1.8	0.0	0.0
Sacramento	69	106	117	29.77	29.84	−.05	73.4	+4.0	108	5	90	51	15	57	48	60	51	55	0.00	−0.2	0	6,078	s.	23	s.	18	28	1	1	1.1	0.0	0.0
San Francisco	155	208	243	29.76	29.92	−.04	59.2	+0.7	86	5	66	50	24	52	32	53	51	82	T.	−0.2	0	7,554	sw.	38	w.	29	13	11	6	4.5	0.0	0.0
San Jose	141	12	110	29.78	29.93		66.2	+1.2	100	5	80	46	13	52	42				0.00	−0.1	0	4,632	nw.	21	nw.	19	24	5	1	1.9	0.0	0.0
South Pacific Coast Region							69.1	+2.6										66	0.01	−0.1										3.7		
Fresno	327	89	98	29.48	29.82	−.03	80.4	+4.6	108	28	96	52	15	64	38	59	41	32	0.04	−0.1	1	6,108	nw.	22	nw.	18	24	4	2	1.6	0.0	0.0
Los Angeles	338	159	191	29.55	29.91	+.01	67.2	+0.8	90	27	75	56	24	59	30	61	58	79	T.	−0.1	0	3,386	sw.	15	sw.	27	7	18	5	5.3	0.0	0.0
San Diego	87	62	70	29.82	29.91	−.01	66.2	+2.3	80	27	71	59	22	62	16	61	59	80	0.01	0.0	1	4,353	nw.	19	nw.	27	9	14	7	5.3	0.0	0.0
San Luis Obispo	201	32	40	29.74	29.96	+.01	62.5	+0.3	85	27	74	44	15	51	35	54	50	74	T.	−0.1	0	2,975	nw.	16	nw.	16	23	7	0	2.6	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.91	29.99		80.0	+0.3	91	14	85	72	13	75	17				1.99	−3.9	19	9,043	e.	38	e.	9	5	18	7	5.5	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.71	29.83	.00	81.0	+0.9	93	8	87	72	6	75	19	76	76	87	12.33	+4.3	20	4,132	nw.	30	s.	5	0	5	25	8.1	0.0	0.0
Colon	38	7	97	29.80	29.84	.00	81.1	+0.7	90	6	87	73	11	76	15	77	77	89	31.23	+17.5	23	3,649	w.	24	n.	20	1	5	24	8.6	0.0	0.0
Alaska																																
Juneau	80	11	54				57.4		81	18	66	39	7	48	32	52	47	69	2.59		10	4,969	s.	27	se.	26	10	6	14	6.3	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100				76.4		85	29	81	67	7	71	13	70	67	72	1.98	+1.1	10	5,240	e.	30	sw.	8	5	18	5	5.5	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, June, 1926*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
St. Johns, N. F	125												
Sydney, C. B. I	48	29.86	29.91	−0.04	55.8	+0.4	65.9	45.8	78	37	3.14	−0.09	0.0
Halifax, N. S	88	29.82	29.92	−.03	56.9	−0.8	66.9	46.9	78	39	5.60	+1.84	0.0
Yarmouth, N. S	65	29.78	29.85	−.10	53.5	−1.5	60.4	46.7	73	38	4.70	+1.94	0.0
Charlottetown, P. E. I	38												
Chatham, N. B	28	29.72	29.75	−.14	58.4	−1.6	69.8	47.0	82	35	2.47	−0.99	0.0
Father Point, Que	20	29.73	29.75	−.12	53.7	+0.7	61.7	45.8	75	40	3.28	+0.30	0.0
Quebec, Que	296	29.52	29.83	−.09	60.0	−1.2	69.8	50.3	80	40	3.19	−0.46	0.0
Montreal, Que	187	29.62	29.82	−.12	61.0	−3.9	70.8	51.2	82	43	4.53	+1.00	0.0
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.59	29.85	−.09	60.4	−4.9	71.9	49.0	88	40	3.38	+0.46	0.0
Kingston, Ont	285	29.57	29.88	−.09	57.9	−5.5	65.8	50.0	75	40	3.31	+0.88	0.0
Toronto, Ont	379	29.47	29.87	−.10	59.8	−3.6	70.2	49.3	83	38	3.47	+0.67	0.0
Cochrane, Ont	930												
White River, Ont	-1,244	28.49	29.79	−.15	52.6	−6.1	65.0	40.2	80	26	4.52	+2.30	0.0
Port Stanley, Ont	592												
Southampton, Ont	656												
Parry Sound, Ont	688	29.16	29.84	−.12	55.7	−6.0	65.8	45.6	77	34	3.54	+1.12	0.0
Port Arthur, Ont	644	29.14	29.85	−.09	55.7	−0.7	65.5	46.0	89	37	4.84	+2.11	0.0
Winnipeg, Man	760	29.07	29.89	.00	58.8	−3.4	68.5	49.1	84	36	3.53	+0.24	0.0
Minnedosa, Man	1,690	28.13	29.93	+.04	55.9	−3.7	66.7	45.1	91	29	1.74	−1.26	0.0
Le Pas, Man	860				54.6		65.9	43.2	81	30	2.95		0.0
Qu'Appelle, Sask	2,115	27.70	29.93	+.06	54.9	−5.0	66.6	43.2	90	28	2.10	−1.32	0.0
Medicine Hat, Alb	2,144	27.64	29.86	+.01	63.6	+1.6	77.5	49.8	99	38	1.14	−1.62	0.0
Moose Jaw, Sask	1,759				58.4		70.4	46.5	95	37	2.00		0.0
Swift Current, Sask	2,392												
Calgary, Alb	3,428												
Banff, Alb	4,521	25.43	29.96	+.12	52.3	+0.8	65.2	39.4	88	28	2.61	−0.72	0.1
Edmonton, Alb	2,150	27.68	29.95	+.11	55.2	−1.7	67.2	43.2	89	30	12.17	+9.31	0.0
Prince Albert, Sask	1,450	28.42	29.98	+.11	57.6	−0.1	69.9	45.3	86	33	0.34	−2.17	0.0
Battleford, Sask	1,592	28.26	29.98	+.12	58.0	−1.5	70.4	45.7	91	34	0.89	−2.42	0.0
Kamloops, B. C	1,262												
Victoria, B. C	230	29.81	30.06	+.05	59.2	+2.9	66.7	51.7	85	47	0.16	−1.04	0.0
Barkerville, B. C	4,180												
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	30.01	30.17	+.05	75.0	0.0	81.3	68.8	85	59	8.84	+2.89	0.0

LATE REPORTS, MAY, 1926

| Stations	Altitude	Station reduced	Sea level reduced	Departure	Mean max.+min.÷2	Departure	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure	Total snowfall
Winnipeg, Man	760	29.05	29.87	−.09	57.8	+6.2	70.4	45.2	90	22	0.83	−1.45	0.8
Minnedosa, Man	1,690	28.06	29.86	−.10	54.0	+5.6	66.3	41.7	83	20	1.00	−0.45	4.1
Calgary, Alb	3,428	26.35	29.90	+.02	52.0	+3.0	66.4	37.7	76	28	0.48	−1.29	4.0
Kamloops, B. C	1,262	28.66	29.94	+.05	58.0	−1.1	69.9	46.2	86	35	0.96	−0.28	0.0
Barkerville, B. C	4,180	25.58	29.87	+.03	43.2	−2.3	55.5	30.9	72	25	3.47	+0.95	0.0
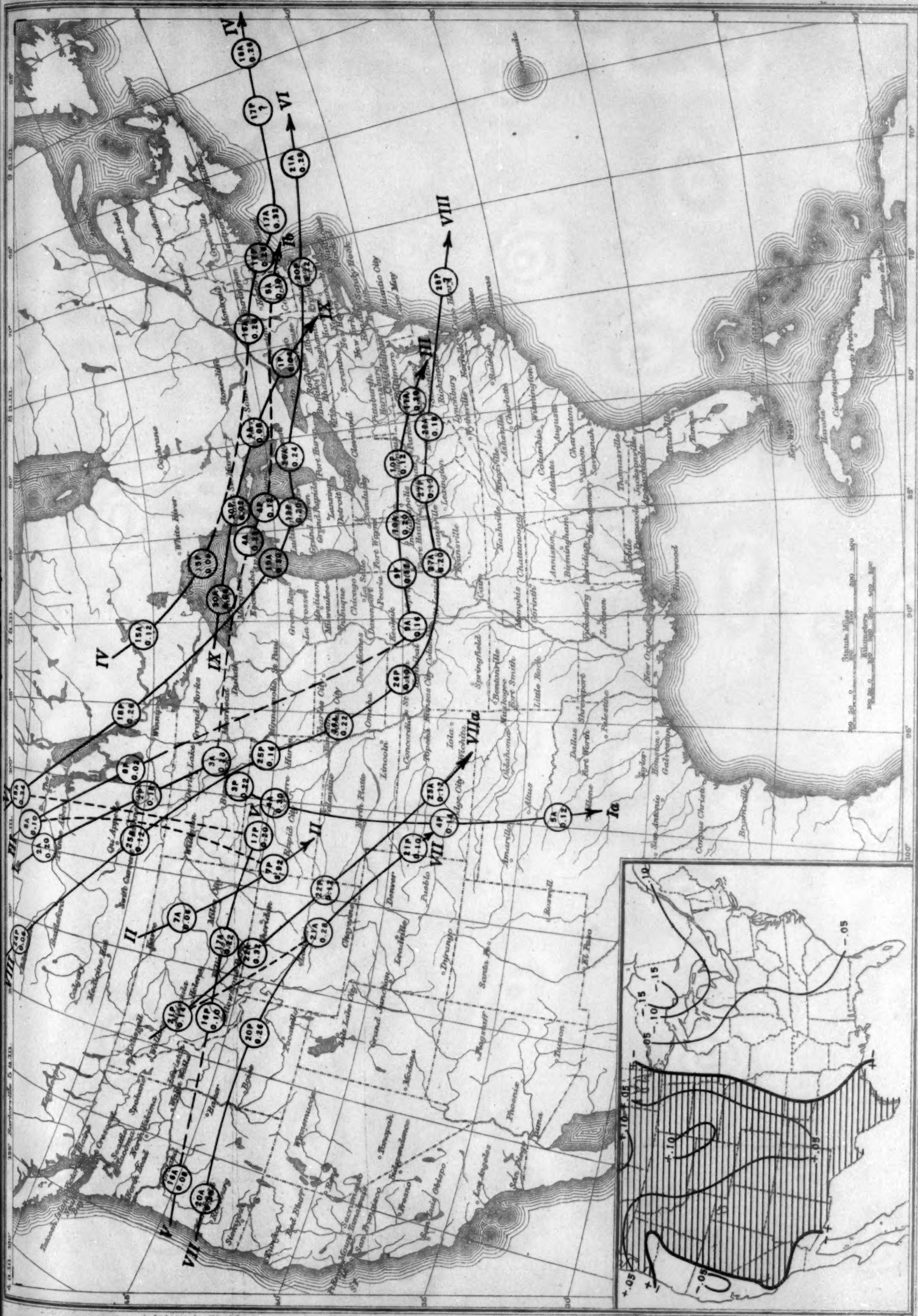
Chart II. Tracks of Centers of Cyclones, June, 1926. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)
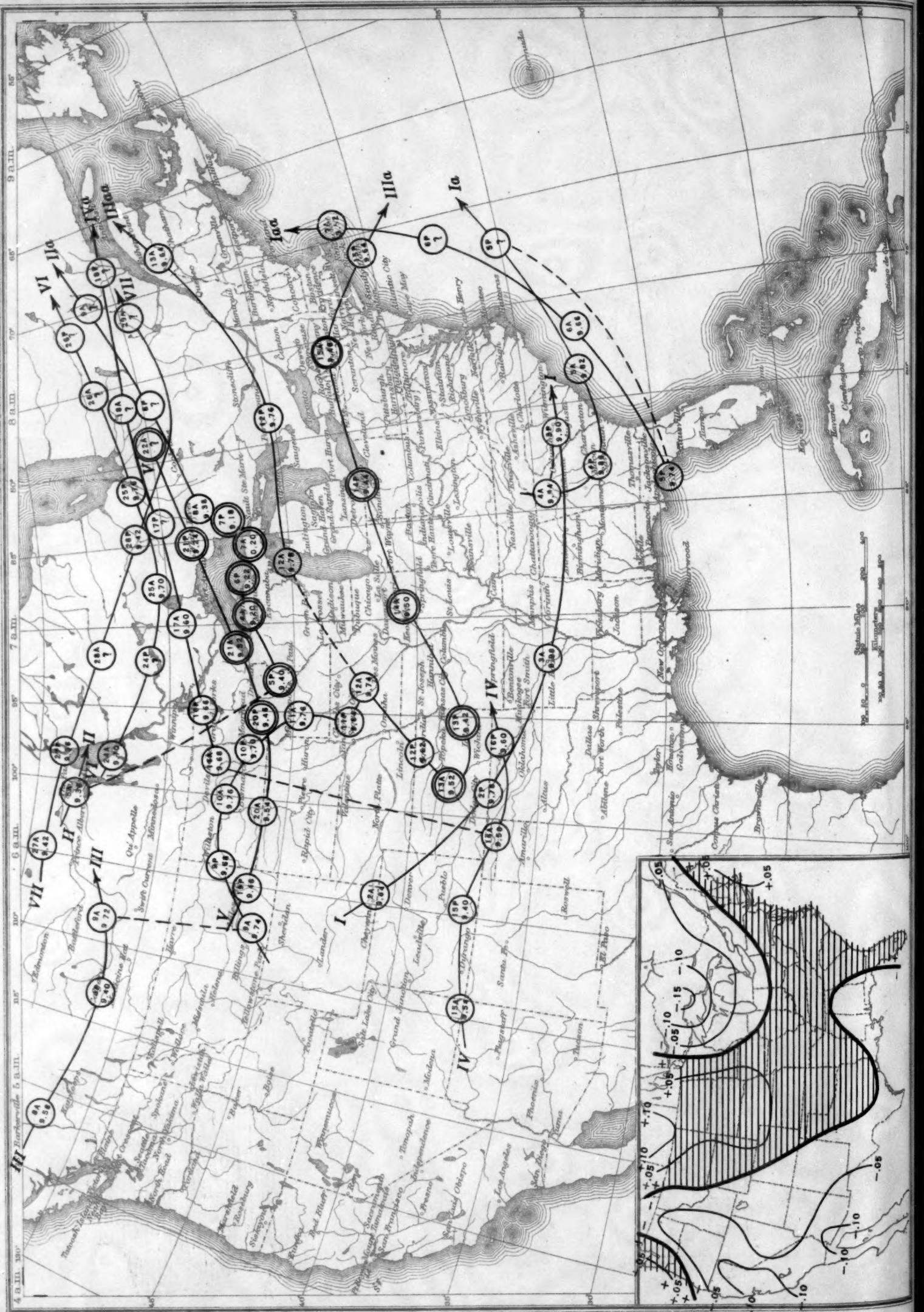
Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart IV. Total Precipitation, Inches, June, 1926. (Inset) Departure of Precipitation from Normal
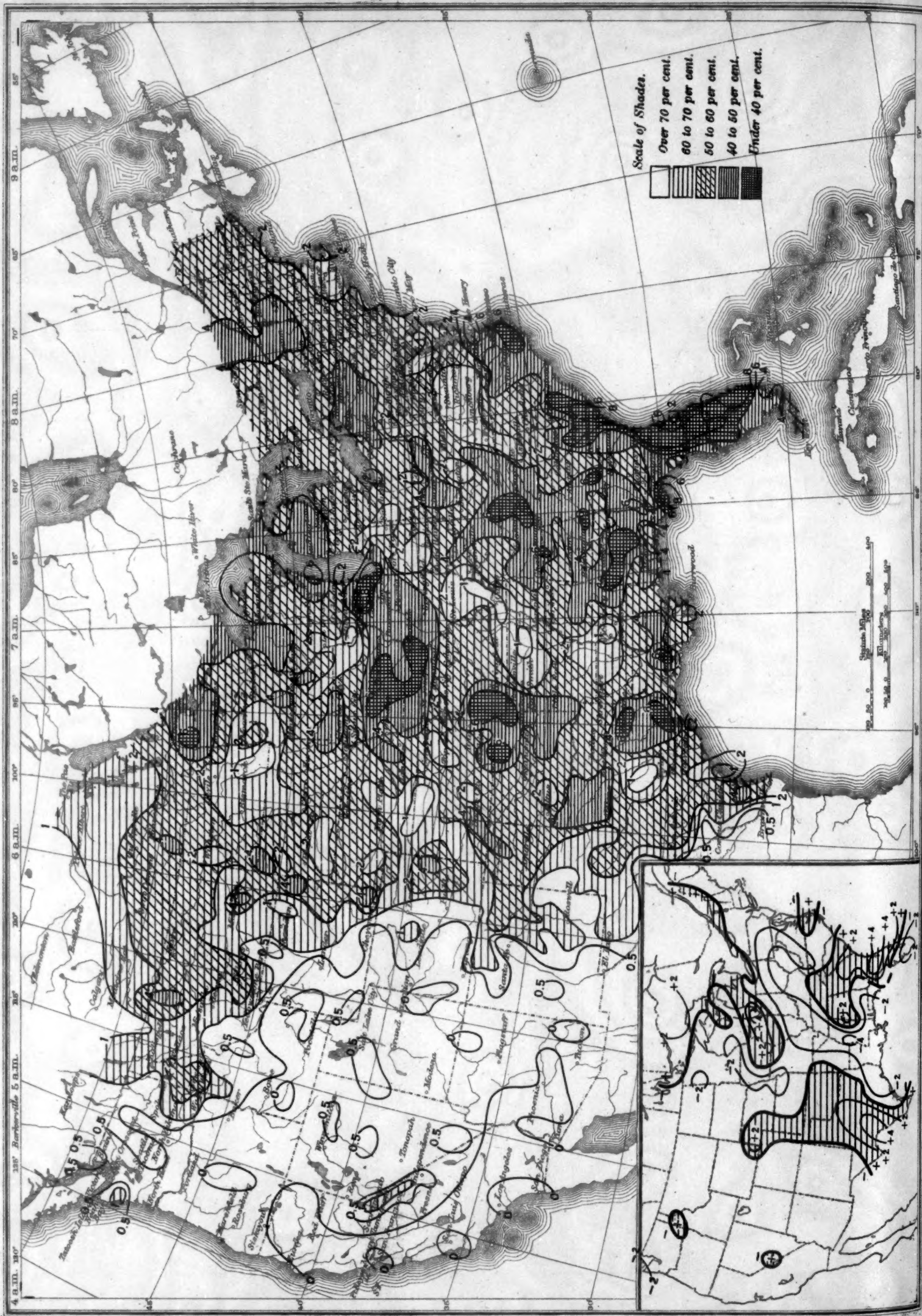
Scale of Shades.

Over 70 per cent.
60 to 70 per cent.
50 to 60 per cent.
40 to 50 per cent.
Under 40 per cent.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, June, 1926

Chart V. Percentage of Clear Sky between Sunrise and Sunset, June, 1926

Scale of Shades.

Over 70 per cent.
60 to 70 per cent.
50 to 60 per cent.
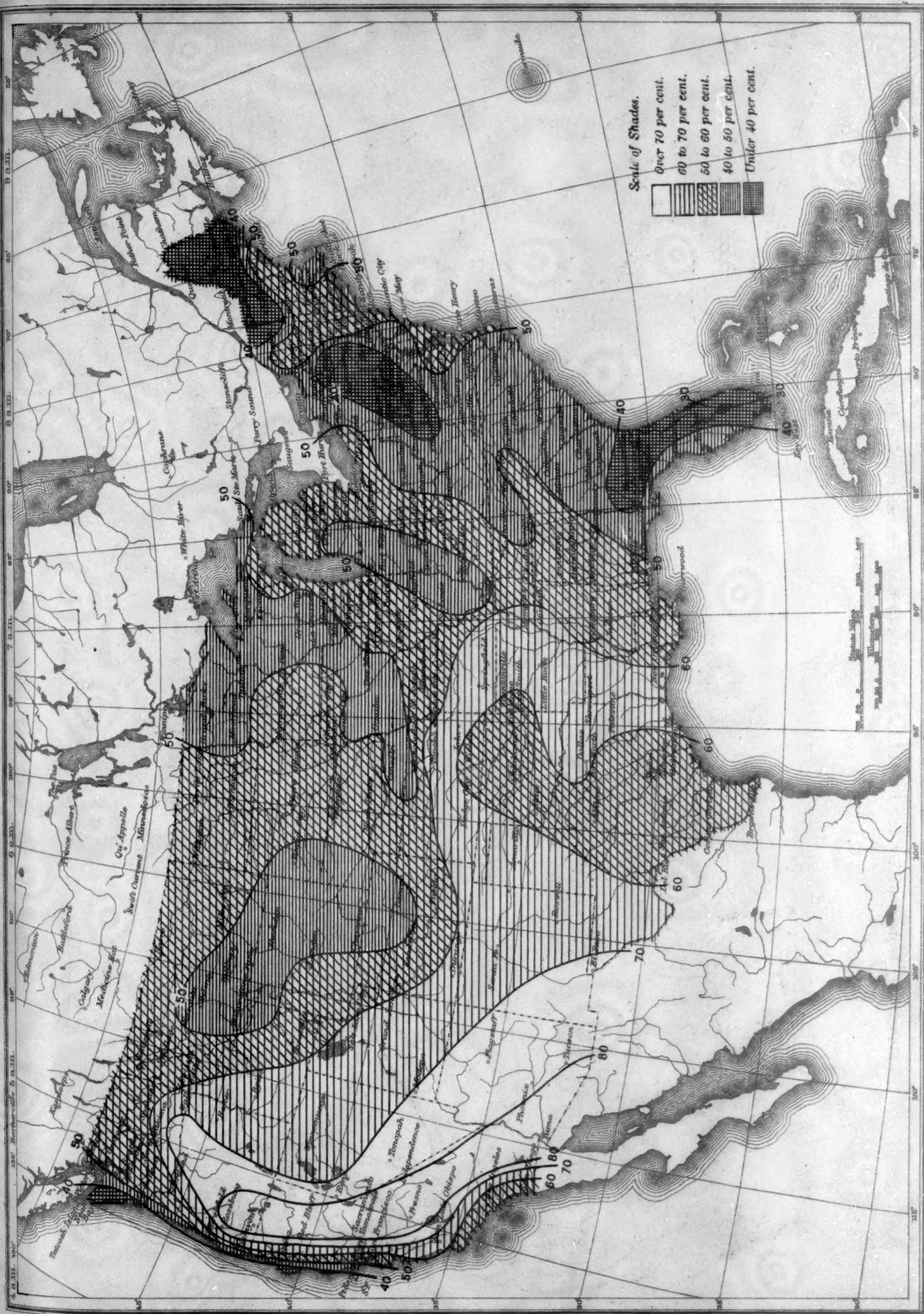40 to 50 per cent.
Under 40 per cent.

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, June, 1926

Scale 1:12,200,000

Kilometers

Statute Miles